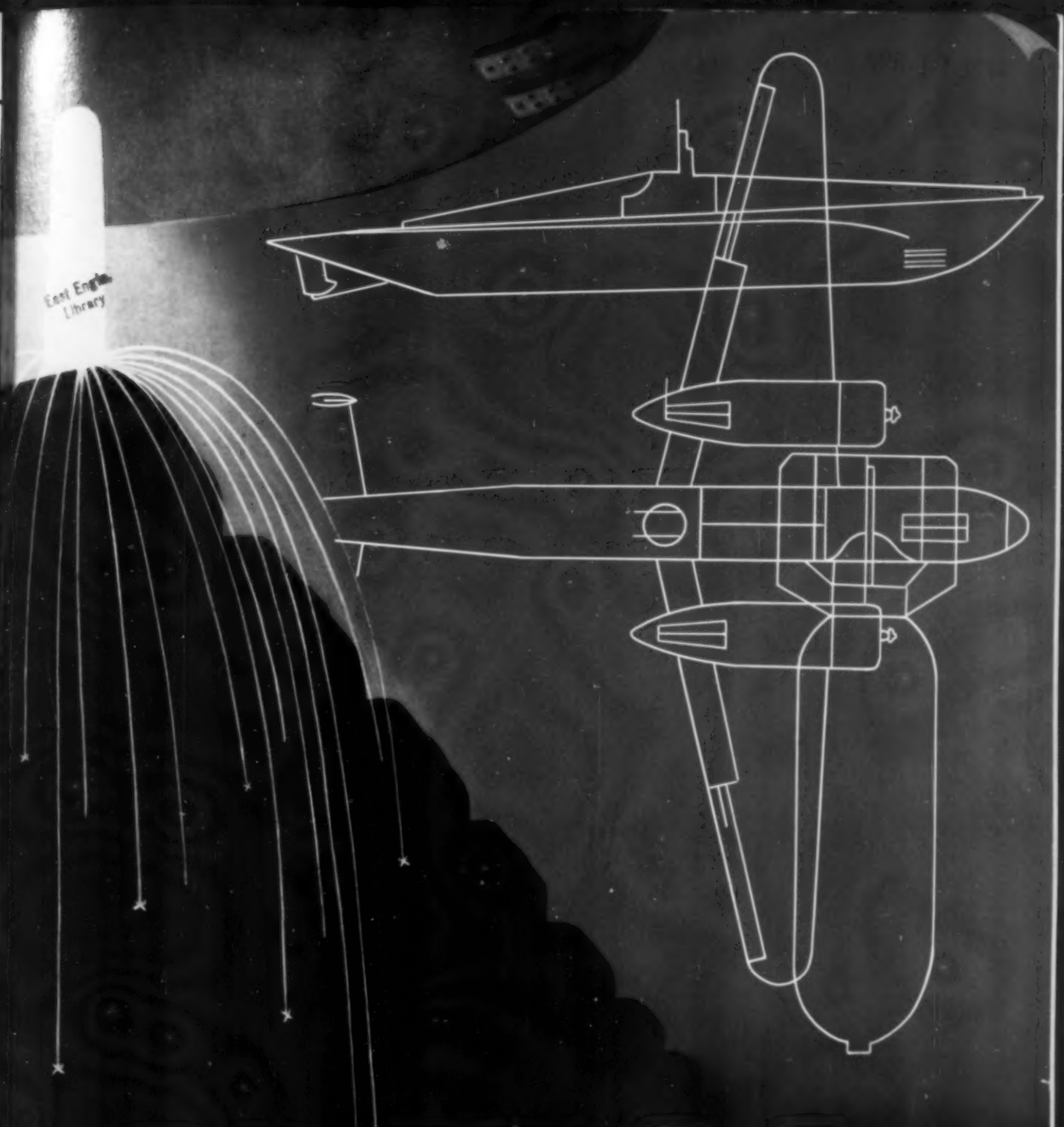

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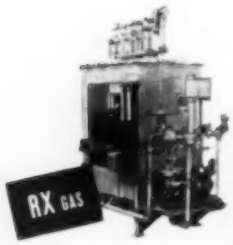

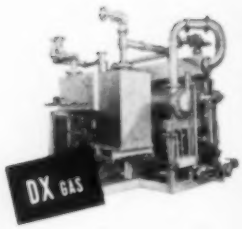

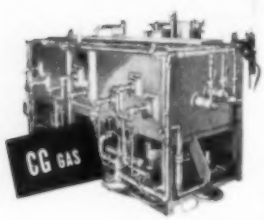

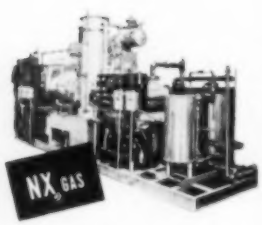

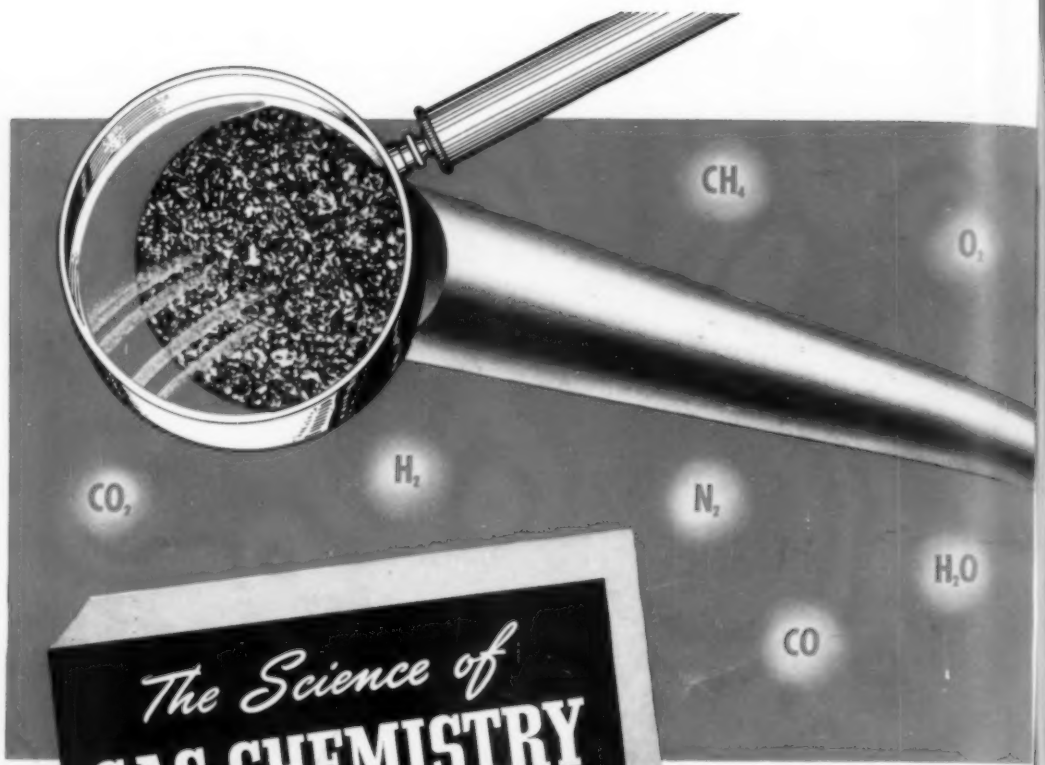

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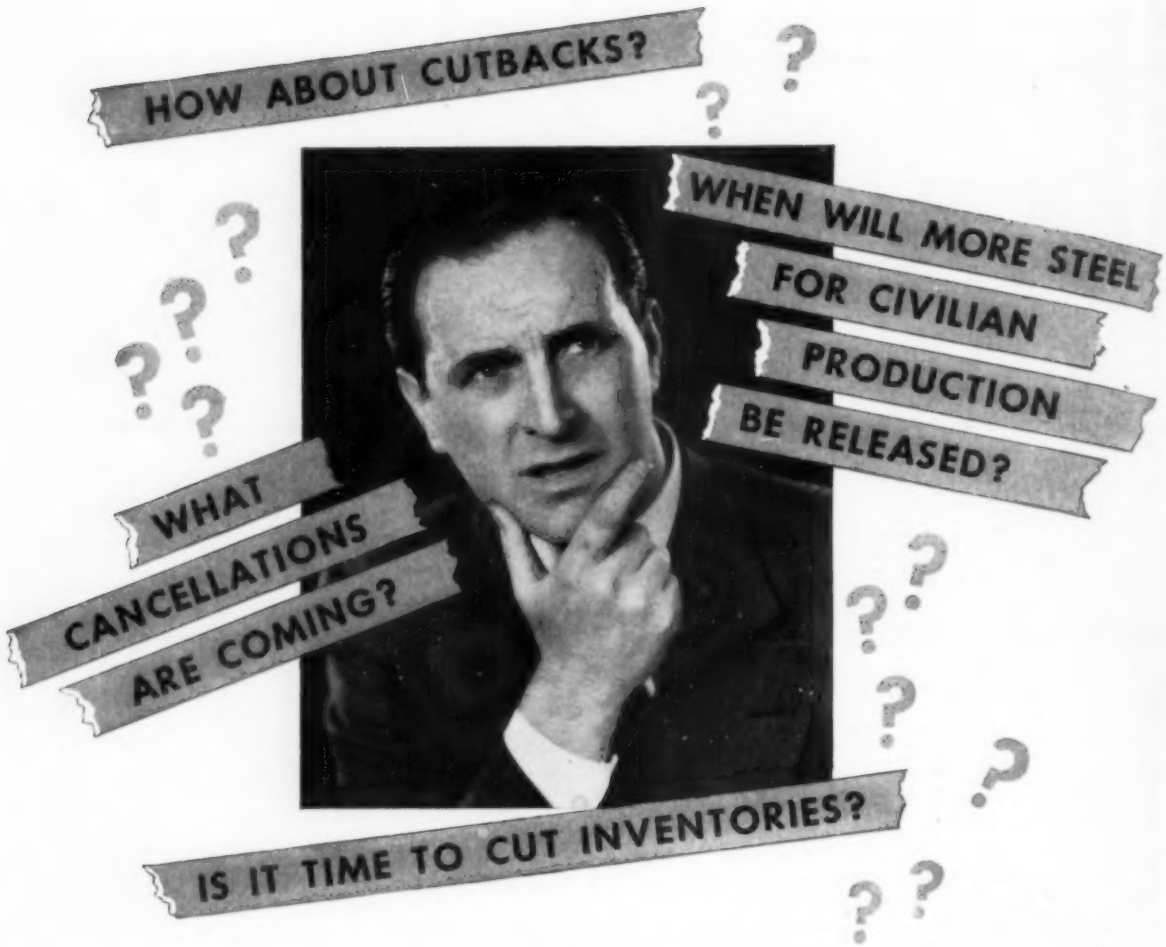
HOW ABOUT CUTBACKS?
WHEN WILL MORE STEEL FOR CIVILIAN PRODUCTION BE RELEASED?
WHAT CANCELLATIONS ARE COMING?
IS IT TIME TO CUT INVENTORIES?

Here are the facts . . .

● Many companies in the metal-working industries have recently experienced cutbacks in war contracts and there is some evidence of planning for partial reconversion to commercial production. As a result, a number of manufacturers are already circulating lists of odd steel stocks and excess inventories. More lists will appear as cancellations, design changes and manufacturing trends follow the tide of war.

While there is no real surplus of steel at the present time, there are sound reasons for a conservative buying policy. First, you will help war production by making steel available for those who need it immediately. Second, it is good business to keep your inventory at a practical working level.

Steel overstocks may be dynamite. Cancellation of a contract or a change in design can overnight leave you with an excessive or obsolete steel inventory. There was a time when this conservative inventory policy might not have been sound from a production standpoint. However—most warehouse stocks have been built up so they now can quickly meet any demand.

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RYERSON STEEL-SERVICE

This is the first part of a discourse before the Boston Chapter, ASM, which established an annual lecture in memory of the late great Albert Sauveur, professor of metallurgy at Harvard University, connoisseur of the art of metallurgy, champion of metallurgical science

The Progress of Metallurgy and Its Problems in Aircraft

By V. N. Krivobok
Formerly
Director of Structural Research, and Chief Metallurgist
Lockheed Aircraft Corp.
Burbank, California

WHEN TIME for thinking and planning is available, the problems of aircraft research will become segregated according to certain basic formulae. A clear exposition of such problems has been recently suggested by a responsible structural engineer,* who named as the objectives of structural research the following:

1. To eliminate structural failures.
2. To reduce the weight of the structure.
3. To reduce design time.
4. To reduce fabrication time.
5. To improve the service and maintenance characteristics of the airplane.

These objectives are applicable to peace and war times, although perhaps not for the same reasons. In the future peacetime this nation will, of course, revert to the construction of commercial planes. Recently compiled data by W. W. Davies in *Mechanical Engineering* for July 1943 establish a very interesting graphic picture of what might be expected — a trend, shall we say, from the developments during the past 40 years. From his mass of technical data, those of special interest to the present occasion are *(a)* gross weight trend, *(b)* wing loading trend, *(c)* useful load ratio trend and *(d)* cruising speed trend. Mr. Davies' four curves are shown on page 658.

The specific problems under basic objectives of research will no doubt be determined by the expected trends. I think that not a few problems which are certain to arise will be directly concerned with the proper choice of structural materials. This may take the form of improving the properties of currently utilized materials — a matter considered very important by structural engineers. Or it may lead to the consideration of substitutes — but if deviations, on a large scale, from aluminum alloys are found to be advisable for airplane structures it will be only because of concrete advantages. To bring out these advantages will require much work, carried out with sympathetic understanding of our multiple problems.

Our time is time of war, time of unexpected and unpredictable contingencies, various changes demanded by combat experience, accelerated production, instructions from governmental agencies. Planned research is subordinate to emergencies. However, amongst endless engineering problems, a basic one faces various officers in the aircraft plant. That one is the selection of the proper material. It may be due to alterations in design, or to unexpected shortage of standard materials. At all times we endeavor to guard against the danger of failure in structural parts, and an airplane is built of many thousands of such parts.

*F. R. Shanley, "Problems in Aircraft Structural Research", Preprint for November 1942 meeting of American Society of Mechanical Engineers.

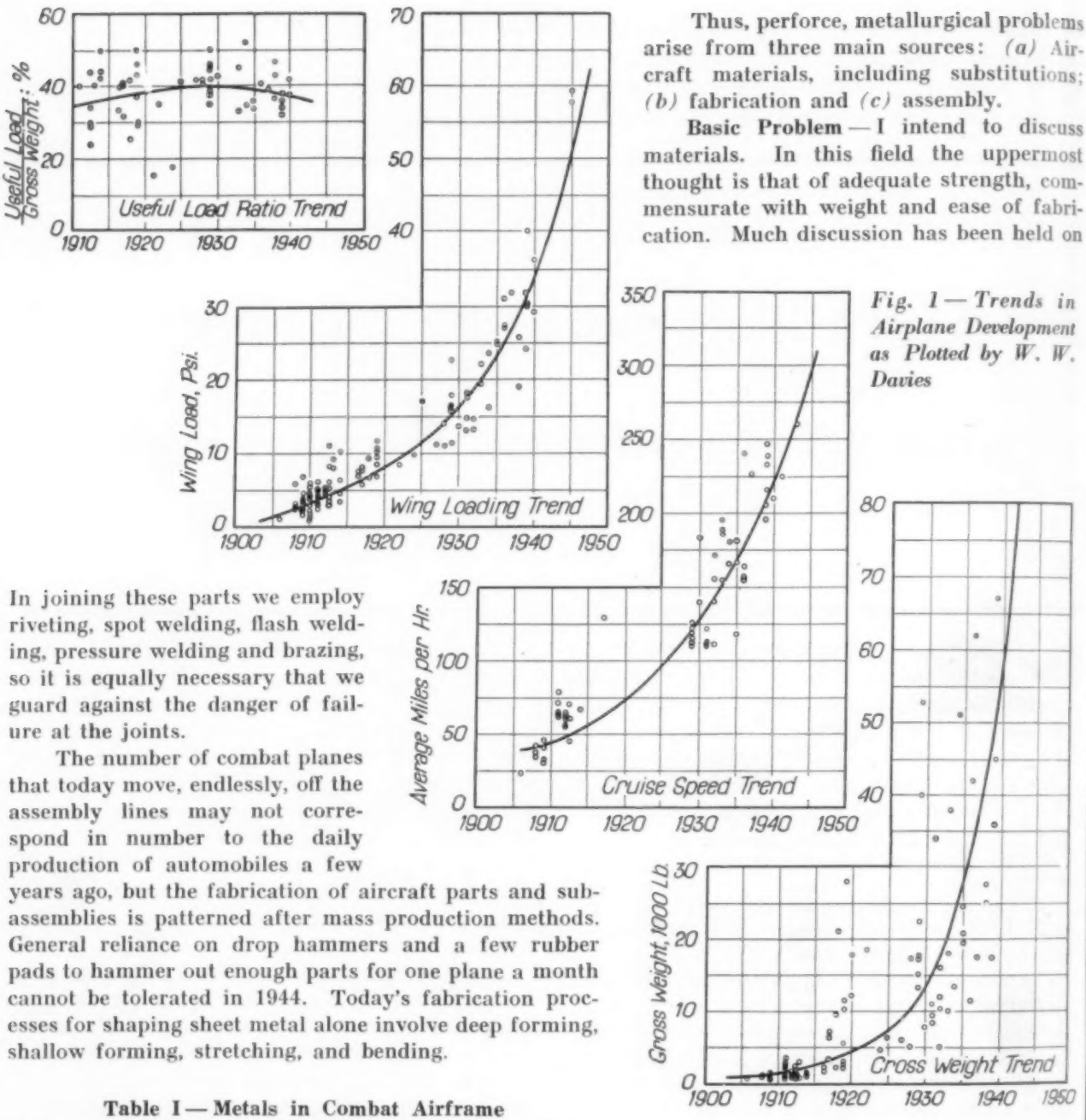


Fig. 1 — Trends in Airplane Development as Plotted by W. W. Davies

Thus, perforce, metallurgical problems arise from three main sources: *(a)* Aircraft materials, including substitutions; *(b)* fabrication and *(c)* assembly.

Basic Problem — I intend to discuss materials. In this field the uppermost thought is that of adequate strength, commensurate with weight and ease of fabrication. Much discussion has been held on relative merits of the light alloys of aluminum and magnesium versus the low alloy steels, carbon steels and stainless steels as main structural materials. Aluminum is still the predominant metal — usually in the sheet form — for summary of materials in the airframe of one of the combat ships see Table I.

Post-Aged Aluminum Alloys — A definite improvement in mechanical properties of the most widely used aluminum alloy (namely 24S, by means of specific metallurgical processing) makes it inadvisable to adopt substitutes right at the present moment — at least on a large scale. Of course the design

In joining these parts we employ riveting, spot welding, flash welding, pressure welding and brazing, so it is equally necessary that we guard against the danger of failure at the joints.

The number of combat planes that today move, endlessly, off the assembly lines may not correspond in number to the daily production of automobiles a few years ago, but the fabrication of aircraft parts and subassemblies is patterned after mass production methods. General reliance on drop hammers and a few rubber pads to hammer out enough parts for one plane a month cannot be tolerated in 1944. Today's fabrication processes for shaping sheet metal alone involve deep forming, shallow forming, stretching, and bending.

Table I — Metals in Combat Airframe

Metal or Alloy	Pounds	Form
Carbon steel	930	1112-1117 bar and rod 1010 sheet 1015 tube
Alloy steel	1655	Series 4100, 4300, NE8600 Stainless steel Bar, rod, sheet, tube
Brass	100	Bar, rod, wire, sheet
Copper	24	Castings and forgings
Aluminum alloy	4784	70 lb. bar and rod 286 lb. castings and forgings 160 lb. tube 3660 lb. sheet 608 lb. extrusions
Total	7493 lb.	

and other characteristics of an airplane involving special problems of weight and bulk have led, and may lead in the future, to other decisions of which we shall speak later.

The improvement in mechanical properties of aluminum alloys, just mentioned, was brought about by deliberately aging the commonly used 24S alloy at elevated temperature, and a further improvement has been achieved by special treatments which the Censor asks us not to divulge. For guidance an outline of this development is shown in Fig. 2, which also illustrates the modifications in the expected physical properties. The advantages that can be derived are illustrated in Table II in percentages of increase over the properties of Standard 24S-T material.

Table II — Relative Change in Tensile Properties
Base is 24S-T

Property	24S-RT	24S-T80	24S-T81	24S-T86
Tensile strength	+10%	+10%	+10%	+18%
Yield strength	+30%	+25%	+38%	+67%
Elongation in 2 in.	−10%	−25%	−25%	−33%

New Alloys — Quite recently, new alloys of aluminum, designated as XA75S and XB75S, have been developed with higher physical properties than 24S, yet with proper corrosion resistance. Their fabricating characteristics should also be comparable to those of the old alloys. Developments have progressed from the experimental stages to production. U. S. Army Air Corps' specifications have been issued so that the consideration of these alloys as structural material is now permissible.

Another comparable product has been brought out, which, at the time of writing (Autumn 1943) had not reached the same stage of development and hence, recognition. Its discussion in detail is furthermore interdicted by the Office of Censorship. However, it is comparable to the "new" alloys mentioned in many of its physical properties. Thus, we now have a choice of materials, surpassing, in their strength, the 24S alloys which are currently used. Properties, based on "guaranteed minimum" values (or specification requirements), are compared at the top of the next column.

Guaranteed Minimum Values

Alloy	Tensile Strength	Yield Strength	Elongation in 2 In.
24S-T	56 to 60,000	37 to 38,000	10 to 13%
24S-RT	62 to 66,000	48 to 50,000	8 to 10%
24S-T81	62 to 64,000	54 to 56,000	5.0%
24S-T86	66 to 69,000	62 to 65,000	3.0%
XA75S (alclad)	66,000	55,000	10.0%
XB75S*	72,000	62,000	8.0%

*Line for XB75S added from specification AN-A-10a (Dec. 14, 1943) since address was given, as a very recent development in the new family of higher strength alloys.

It may be seen that the most noticeable difference in all except XB75S is in the elongation which, with certain limitations that will be brought in later, is significant as an indication of formability. Since forming characteristics are an all-important factor, the alloy XA75S would appear to be preferable over the former varieties of 24S. This would be an erroneous conclusion, because forming of the parts is intended to be done *prior* to artificial strengthening of 24S alloy; in the latter condition this alloy is not suitable for forming, except possibly to a very limited degree.

Important though this development is, utilization of alloys with such improved physicals has not yet reached that stage when full advantage of their properties can be taken. In the new varieties of 24S it is primarily a matter of reproducible properties — a matter which requires close control of factory processing and necessitates the use of up-to-date equipment

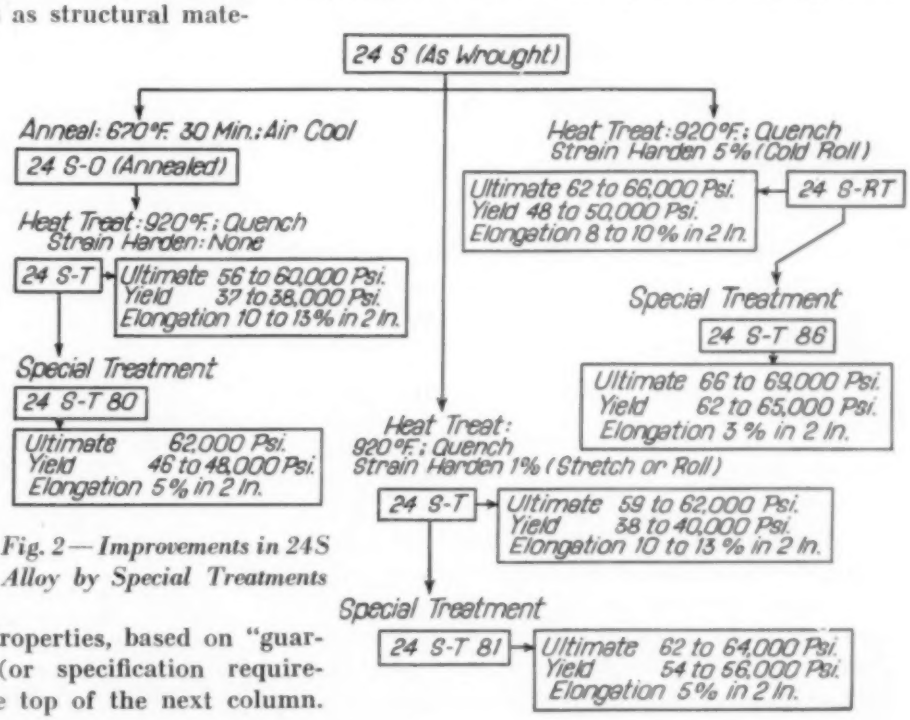

24 S (As Wrought)
Anneal: 670°F. 30 Min.; Air Cool
24 S-O (Annealed)
Heat Treat: 920°F.; Quench
Strain Harden: None
24 S-T
Ultimate 56 to 60,000 Psi.
Yield 37 to 38,000 Psi.
Elongation 10 to 13% in 2 In.
Special Treatment
24 S-T 80
Ultimate 62,000 Psi.
Yield 46 to 48,000 Psi.
Elongation 5% in 2 In.
Heat Treat: 920°F.; Quench
Strain Harden 5% (Cold Roll)
24 S-RT
Ultimate 62 to 66,000 Psi.
Yield 48 to 50,000 Psi.
Elongation 8 to 10% in 2 In.
Special Treatment
24 S-T 86
Ultimate 66 to 69,000 Psi.
Yield 62 to 65,000 Psi.
Elongation 3% in 2 In.
Heat Treat:
920°F.; Quench
Strain Harden 1% (Stretch or Roll)
24 S-T
Ultimate 59 to 62,000 Psi.
Yield 38 to 40,000 Psi.
Elongation 10 to 13% in 2 In.
Special Treatment
24 S-T 81
Ultimate 62 to 64,000 Psi.
Yield 54 to 56,000 Psi.
Elongation 5% in 2 In.

Fig. 2 — Improvements in 24S Alloy by Special Treatments

which is not always available. It also is not easy to insure the proper amount of pre-stretching of 24S-T and 24S-RT — whether of wide sheets or heavier plates. Thus, initial difficulties have been experienced in duplicating the properties of improved material; we have yet to know the precise effect of composition, the manner in which cold working is accomplished (that is, by rolling or by stretching) and, possibly, the influence of some unknown detail in processing. Alloys 24S-T80, 81 and 86 are receiving much attention from some airframe builders and their incorporation into design may be expected. Others seem to favor "new" alloys. Whatever is the final selection, weight will be saved by reason of the improved physical properties.

As was mentioned, the XA75S and XB75S alloys have been recognized by official channels to the extent that material specifications have been issued. [Since the delivery of this lecture the definite preference for XB75S is to be recognized. However XA75S is still of much interest, not only because it is a "prototype" of XB75S, but because its use is experimentally tried.] The specifications for alclad XA75S material call for properties as shown in the list above. It is to be noted that actual physical properties appear to be quite consistent not only from sheet to sheet but also in various lots. In addition, the test results show so far that typical values for tensile and yield strengths of the commercially processed material run considerably higher than the values incorporated in Government specifications. (Incidentally, this is also true of other alloys.) Strength values are dependent upon the direction of rolling, but this difference is approximately the same as has always been known for other aluminum alloys. Ductility (elongation) in the direction of rolling and perpendicular to it is about the same. This is shown in data for samples from a 0.064-in. sheet:

Tensile Data for Alloy XA75S-T (0.064-in. Sheet)

	Parallel to Rolling	Perpendicular to Rolling
Tensile strength	68,000 to 71,800 psi.	67,600 to 69,200 psi.
Yield strength	62,700 to 63,100	59,300 to 59,600
Elongation in 2 in.	13.0 to 14.0%	12.0 to 13.0%
Elongation in ¼ in.	23.0 to 27.0	25.0 to 26.0

Compressive Strength — If one is to base his opinion on available published data it will be concluded that the property of compressive strength is not of much importance to the metallurgist, yet Lockheed's chief stress engineer has informed me that approximately 60% of aircraft parts are critical in compression! For this reason the consideration of compressive strength of the material and the variables that may affect it is all-important. A study of the relative merits of 24S-T81 alloy and XA75S indicates that there is little to choose between them. On the other hand, 24S-T86 appears to have appreciably higher column strength than XA75S.

Effect of Spot Welding — Consideration of the artificially aged (or as it is at times called "post-aged") alloy 24S-T led to the necessity of spot welding certain structural parts both *before* and *after* aging. Because of this decision it is imperative to determine the effect of spot welding on aged material as well as the effect of aging on the strength of spot welded 24S-T. After all, the improved properties are of no consequence if they are altered by the method of joining.

Results on spot welding of aged material were satisfactory. Under identical machine settings, welds were produced of similar shear and tensile strength, consistency and ductility. A few figures depicting actual test results might be of interest:

Material Welded	Ultimate Shear Strength	Ultimate Tensile Strength
0.025-in. 24S-T to 0.032-in. 24S-T-RT	419.0 lb.	113.0 lb.
0.025-in. 24S-T to 0.032-in. 24S-RT80	449.0	92.0
0.064-in. 24S-T to 0.064-in. 24S-RT	950.0	498.0
0.064-in. 24S-T81 to 0.064-in. 24S-RT81	891.0	466.0

Aging of spot welded samples introduces a basis for further inquiries. Comparison of shear test results showed that the effect of aging might be either positive or negative, that is, the shear strength of the material aged after spot welding may be either raised or lowered in comparison with the shear strength of the material before aging. Based on 100 shear samples tested in each group the pertinent figures for 0.40-in. gage are as follows:

Material Welded	Ultimate Strength			Lower Control Limit*	Difference in Average Strength of Aged and Un-Aged Welds
	Max.	Min.	Av.		
24S-T	780	400	655 lb.	433 lb.	
24S-T80	770	510	661	536	+1%
24S-T	860	470	709	475	
24S-T81	785	290	610	328	−14%

*Lower control limit is that value above which 99.9% of all spot welds will fall, providing the welding machine remains under control. U. S. Army minimum for spot welds (shear strength) of 0.40-in. 24S-T alloy is 345 lb.

Fig. 3 — Moderate Sized Part, Dished and Curved in Double Acting Press Between Permanent Dies

When tested in tension it is found that the ultimate strength is uniformly lowered 13 to 15%. Even with this decrease the values are above the required U. S. Army minimum. While this circumstance is of a reassuring nature, the fact remains that by aging after spot welding we lose at least part of the gain acquired by the special treatment.

It is of interest to note that the failure in all instances took place by "pulling of the button". Metallographic examination reveals no apparent difference in the structure of un-aged and aged samples, yet it is obvious that aging has produced *some* change which is responsible for the described lowering of ultimate tensile strength invariably observed. Incidentally, exactly similar observations were communicated to me by two other companies.

I do not have at this time data on how the XA75S or XB75S alloy would behave under similar testing procedure. Nor do we know whether or not it may be possible to control the processing of 24S alloy so as to minimize the effect of post aging after spot welding. Some interesting problems are ahead. *Preliminary* observations, which I have just described, indicate various paths for research, and when the answers are known the relative merits of the new and interesting materials may be more intelligently evaluated.

Formability — One of the highly important questions which arise when any structural material comes up for consideration is its forming properties as compared with standard alloys. In this connection it may be of interest to mention that the vast number of formed airplane parts can be divided as to the temper in which they are manufactured as follows: 50 to 60% of all parts are made of 24S-O; 10% of all parts of 24S-W and 40 to 30% of all parts of 24S-T. Thus, comparable evaluation of new alloys will have to be made in condition known as "O" (annealed) and "T" (heat treated and aged at room temperature). Extensive and conclusive data are not available at the time of writing but the indication is that XA75S and XB75S are quite comparable to 24S in similar tempers, allowing for certain reservations: Forming of the wrought aluminum alloys has made remarkable strides (especially in handling alloys in "T" condition) in the past two or three years. The ability to form heat treated and aged sheet (with the obvious advantages of such procedure), or the necessity to make parts of annealed sheet and then heat treat them to "T" temper, depends much on the geometry of the part. Consideration of such typical variables as spring-back — and as its consequence, over-forming — and bend radii enter into the decision. Much also depends upon the ingenuity of the tool designer, and the equipment available.

These matters are mentioned here because it is no longer true that slight or even considerable differences in basic properties constitute an insurmountable barrier to the problem of successful forming.

Conversely, the mere fact that what we may call "basic properties" of certain alloys determined in a standard fashion are for all practical purposes identical or very similar does not guarantee that forming problems will not arise. We have shown that "ductility" is not necessarily truly portrayed by the values for elongation on the standard sample, 0.5 in. wide, 2-in. gage length, and may be considerably re-evaluated if other gage lengths or widths of the test sample are employed. It is for this reason that at Lockheed we have adopted the practice of measuring elongation in ¼-in. gage length. This measure, together with others, somewhat more complicated, gives a much better picture of what may

be expected. In fact, comprehensive studies of forming technique have originated from the concept of a variable distribution of elongation over the conventional 2-in. gage length.

Table III — Ductility (Elongation) of Steels With Approximately the Same Tensile Strength Vs. Gage Length

Type of Steel	Tensile Properties				Drawing Limits r ÷ R	Gage Sheet Tested
	Yield	Tensile	Elongation			
			on ¼ In.	on 2 In.		
S.A.E. 4610	72,000	88,400	21	18	0.52	0.028 in.
NE 8630	70,250	89,200	43	20		0.032
S.A.E. 8615; C.R.		137,800	13	7		0.018
NE 8817; C.R.	121,800	142,400	22	7		0.012
S.A.E. 8615; C.R.	122,900	127,100	19	9	0.50	0.024
NE 8817; C.R.	117,300	128,600	29	13	0.49	0.025

A good illustration can be had from the study of data on certain commercial alloy steels. In Table III two pairs of steels of the same tensile strength and *elongation in 2 in.* are selected, one pair in as rolled condition, one pair in cold rolled condition. Comparable values for *elongation in ¼ in.* are approximately in proportion 1:2.

In the same table are also included two lines of data showing that two cold rolled steels of different analysis but of the same tensile strength may have considerably different elongation, either measured on 2-in. or ¼-in. gage length.

A summary of similar information on aluminum alloys under discussion is presented in Table IV. Let us make a few observations. In the annealed condition the XA75S alloy appears to be less ductile than 24S-O, yet the ductility of the XA75S-T (heat treated) appears to be only slightly less than that of 24S-RT or 24S-T80. Whether this relatively small lowering of ductility (as measured in ¼ in. elongation) will permit or preclude forming of parts from XA75S-T instead of 24S-T or 24S-RT is as yet unknown. It is doubtful if general conversion could be made, even if desirable; it should be anticipated that in certain cases this small difference will be just enough to prevent forming in production.

Please do not have the impression, against which I already warned you, that formability can be determined by such a simple experiment as measuring elongation on the small gage length. Bending, stretching, deep-drawing — all these operations are influenced not only by the inherent properties of materials but also by many circumstances including skill in tooling design. A pair of photographs show a pan made on a double-acting press with metal dies and a steel part made on the drop hammer.

Ferrous Versus Non-Ferrous Alloys — A short summary of the properties of certain low alloy steels was originally included (but later omitted) with the idea of providing a simplified comparable basis for the discussion on "Aluminum vs. Steel". I surmise that by this time I am expected to prophesy upon the use of other metals in aircraft construction, primarily steel and magnesium, instead of aluminum. Obviously, detailed discussion of "ferrous vs. non-ferrous" metals cannot be attempted in small space.

This much I am willing to say: Generalized statements, and exaggerated rumors which purport to predict the elimination of aluminum alloys and the substitution on a large scale of either magnesium or steel (including stainless) or both, are, in my opinion, without foundation. While advantage may be taken of certain characteristics of a metal, as for example lower density of magnesium; while careful design can overcome certain disadvantages, as for example thinness of steel (to satisfy strength-weight ratio) — any general change from one material to another is impossible in time of war production.

Table IV — Typical Values for Elongation (¼-In. Vs. 2-In. Gage) for Aluminum Alloy Sheet

Alloy	Gage	Yield; Psi.		Ultimate Tensile	Elongation	
		Tensile	Compressive		on ¼ In.	on 2 In.
24S-O	0.032 in.	10 to 13,000		25 to 31,000	28 to 32%	17 to 21%
24S-T	0.040	51 to 52,000		67 to 68,000	27 to 30	19 to 20
24S-RT	0.040	35 to 59,000		69 to 70,000	25 to 27	14 to 15
24S-T80	0.040	48 to 49,000		65 to 66,000	22 to 25	12 to 13
	0.051	46 to 47,000		63 to 64,000	20 to 23	11 to 12
24S-T81	0.040	65 to 67,000		71 to 72,000	14 to 18	6 to 7
	0.051	59 to 60,000		66 to 67,000	17 to 21	7 to 8
24S-T86	0.040	69 to 70,000		72 to 73,000	15 to 17	5 to 6
	0.051	67 to 68,000		71 to 72,000	11 to 14	6 to 7
XA75S-O	0.064	14 to 15,000	15 to 16,000	29 to 30,000	27 to 32	10 to 15
XA75S-T	0.064	59 to 63,000	59 to 63,000	67 to 71,000	23 to 27	12 to 14

When gradual introduction of a new material is justified it is best done on a new design.

But first we must *know* the new material, and appraise the advantages such a material offers. Then we must seek its service record. All of this works against change in established practices, especially since the accumulated service record of aluminum is satisfactory.

Even in isolated specific cases, substitutions, desirable for one reason or another, may not be possible at present. But *after the war* new circumstances and new problems will arise. To what extent they will necessitate or make advisable "radical" changes I do not believe anyone can predict. One thought, however, is based on mature and careful judgment: Close technical cooperation will have to be an actual, living thing between two classes of engineers, consumers and producers, respectively — one devoting their time to aircraft building and the other making the metals with which to build.

With the advances in aluminum alloys technology which have been stated, steel as a "substitute" material will find it difficult to compete with light metal alloys on the strength-weight basis. I am convinced, however, that this belief of structural engineers may not always be successfully argued and that many considerations, among them design features, size, weight, etc., will be the final governing factors in the selection of structural materials.

Furthermore a fact of far reaching importance is this: Steels which are successfully used in many industries do not require close control of certain of their mechanical properties. The same steels, *perfectly admissible as sound engineering material*, are not readily adaptable to the very exacting requirements of aircraft design.

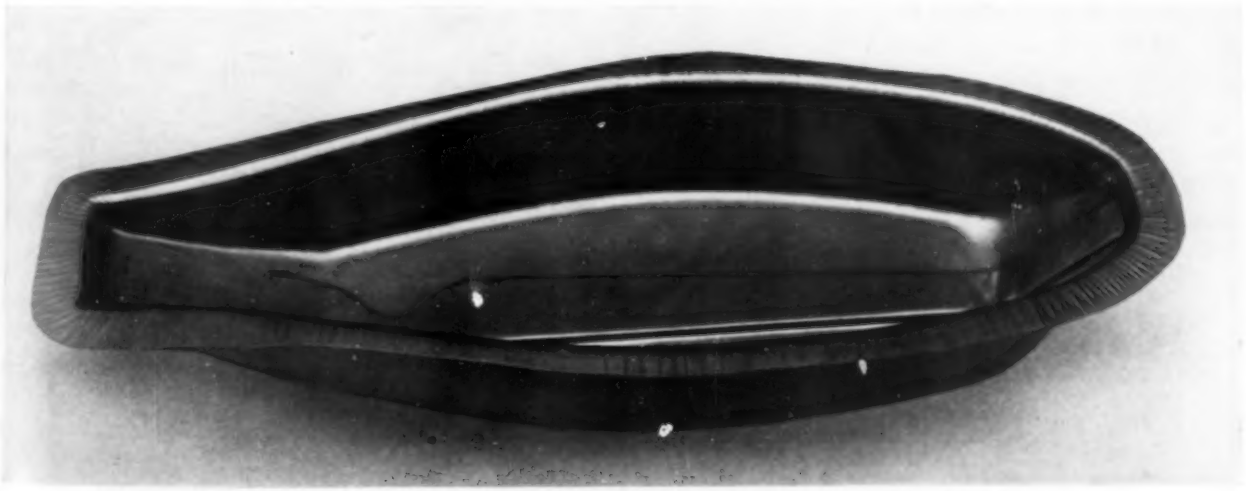
The specific requirements of the aircraft industry, such as are associated with difficult forming problems, and the consequent necessity to have steels with mechanical properties controlled to within prescribed limits, must be recognized — at least until we learn more about the relationship between formability and certain properties of steels. Acceptance of responsibility for the control of these requirements is very essential to airplane builders. More than once this matter has been discussed with important and unprejudiced men in the aircraft industry; invariably a keen interest in the possibilities of steels was evident. But — to stress it again — this interest was always predicated on the assumption that steels with closely controlled physical properties will be available (developed, if necessary) for airframe construction.

Without such control (admittedly requiring changes in processing) and the introduction of certain but not impossible difficulties, the commercial variety available for the job now does not have a fair chance. I am well acquainted with concrete efforts that have been made by some of our friends in California; the results did not alter my opinion.

In addition to the points noted, economic considerations due to the large quantities of materials involved and the large price differences have and will exert a marked influence on the use of steel in place of aluminum in many instances.*

*Editor's Note — In the next installment a discussion of magnesium alloys will be presented. The third short installment will discuss steel castings and forgings for airframe parts.

Fig. 4 — Half-Shell of Steel Tank. Made of S.A.E. 1010 Steel, 0.037-In. Gage, Made on Drop Hammer. Stamping is 2 ft. 8 in. long



"X" Constituent Formed in Alloy Steel on Continuous Cooling

By Arthur R. Kommel
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United Engineering & Foundry Co.
Vandergrift, Pa.

AN EASY QUIZ QUESTION in a metallurgy course would be "Which contains the most ferrite, steel after annealing or after normalizing?" The bright student would answer, "Annealing", and of course he'd be right. But in the case of certain steels we have recently examined, he'd as certainly be wrong. In a series of 0.50 to 0.60% carbon, chromium-molybdenum cast steels, which had been given heat treatments simulating the annealing and normalizing treatments for heavy castings, the writer was somewhat nonplused to find considerably more ferrite in the normalized than in the annealed specimens!

The heat which best demonstrated the behavior was an induction furnace heat of the following analysis: 0.59% C, 0.78% Mn, 0.041% P, 0.031% S, 0.35% Si, 0.50% Cr, 0.45% Mo.

When given a double anneal at 1750 and at 1550° F., the structure was as shown in Fig. 1 (nital etched and magnified 100 diameters), while the structure after a 1750° F. anneal followed by a 1650° F. normalizing treatment was as shown in Fig. 2. Very little free ferrite shows in the annealed steel; one would not be far wrong in saying it looks like a eutectoid steel, almost wholly of fine pearlite. Most of the pearlite in the *normalized* steel is too fine to resolve at this moderate magnification, but there is a considerable amount of unetched white constituent which would be spotted as ferrite.

Cooling rates were as shown in the table below.

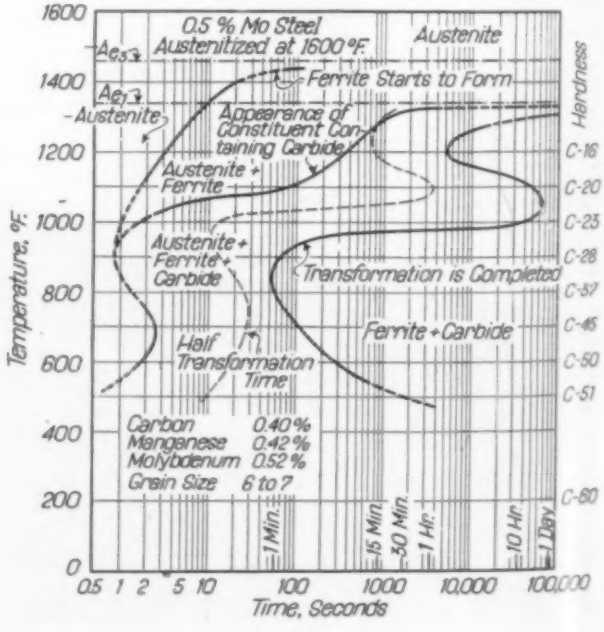
Cooling Rates, °F. per Hr.

RANGE, °F.	ANNEALING	NORMALIZING
1650 to 1600	60	400
1600 to 1500	50	375
1500 to 1400	40	275
1400 to 1300	10	225
1300 to 1200	10	150
1200 to 1100	15	115
1100 to 1000	15	85
1000 to 900	10	65
900 to 800	10	45

To determine whether the reactions were reversible, specimens cut adjacent to those examined were re-treated; the specimen which was previously annealed was normalized and vice versa. This re-treatment resulted in a reversal of structure; the steel of Fig. 2 was now indistinguishable from Fig. 1.

It was further found that the difference in temperature of the second treatment had no effect on the amount of ferrite. Figure 3, at 100 diameters, shows the structure of the same heat when annealed at 1750 and again at 1650° F. (the ordinary normalizing temperature). It is similar to that of Fig. 1.

Isothermal Transformation Diagram for 0.50% Molybdenum Steel (0.40% Carbon). Courtesy U. S. Steel Corp. Research Laboratory



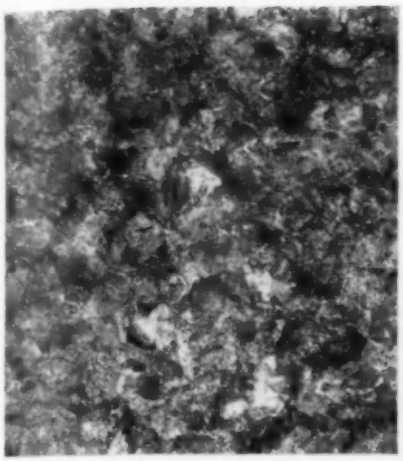
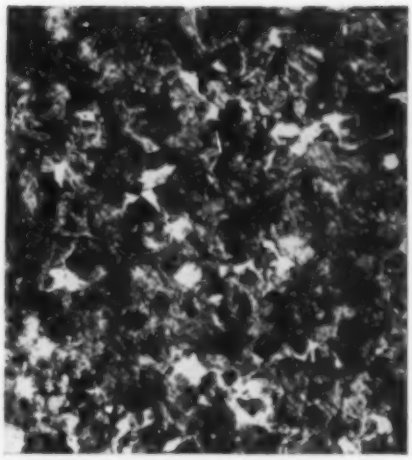


Fig. 1 (at left) — Cr-Mo Cast Steel Double Annealed at 1750 and at 1550° F. (100 diameters)

Fig. 2 (at right) — Cr-Mo Cast Steel Annealed at 1750° F. and Normalized at 1650° F. (100 diameters)



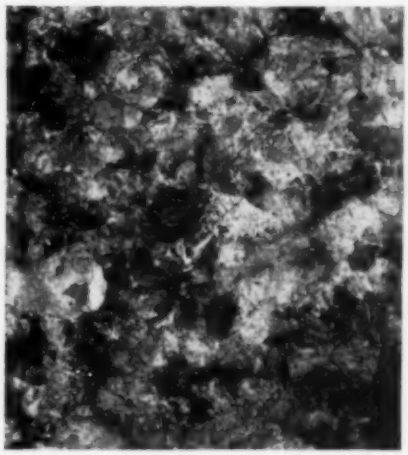


Fig. 3 (above) — Same Steel Double Annealed at 1750 and 1650° F.

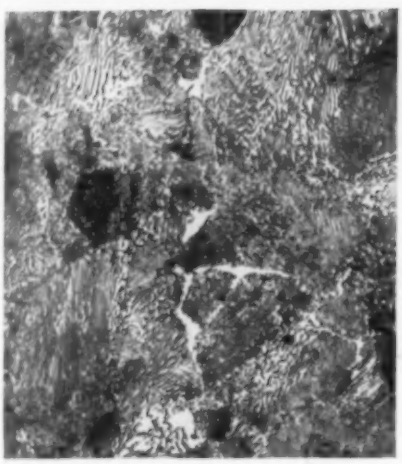


Fig. 4 (at left) — Fig. 1 at 500 diameters

Fig. 5 (at right) — Fig. 2 at 500 diameters

Since the difference in structure, therefore, appears to be due to the cooling rate, the structures shown in Fig. 1 and 2 were examined at higher magnification. Figures 4 and 5 at 500 diameters are the result. The annealed sample, Fig. 1 and 4, shows a pearlitic matrix while the air-cooled specimen, Fig. 2 and 5, shows a structure intermediate between a purely lamellar and purely acicular matrix.

It thus appears that the extra ferrite in the normalized sample is more likely the "X" constituent, the unexpected and increased amount of pre-eutectoid ferrite formed at isothermal transformation temperatures intermediate between those where definitely lamellar and definitely acicular products are formed by the transformation of austenite. This phenomenon was first reported by Davenport in the Campbell Memorial Lecture (1939 ⊜ *Transactions*, page 837), and has since been found upon isothermal transformation of many alloy steels.

I have no "S-curve" to present for a steel of this composition. However, it would doubtless be much like the one reproduced at the left, taken from page 45 of the very excellent "Atlas of Isothermal Transformation Diagrams" recently published by United States Steel Corp. The amount of true pro-eutectoid ferrite will be roughly proportional to the width of the area marked "Austenite + Ferrite", an area which is widened by more molybdenum. The lower the transformation, the smaller would be the amount of true pro-eutectoid ferrite. However, for our steel, a dotted line would probably extend from the region of the shelf at 1100° F. down into the "Austenite + Ferrite + Carbide" field, and would indicate the beginning of a second reaction stage in this temperature region, the product of the first stage being the ferritic "X" constituent. The extra alloy in our heat would tend to move the lines to the right rather than to widen the areas, while the higher carbon content would narrow the "Austenite + Ferrite" field by moving the beginning of transformation to the right.

Apparently the steel composition and normalizing rate used by us were such that transformation of austenite occurred in just the proper range for the "X" constituent to form. It can also be predicted that a fortuitous combination of cooling rate and composition would lead to similar structures upon continuous cooling transformation of other alloy steels. ⊜

Improved Castings From Better Foundry Metallurgy

CONTRIBUTIONS to the group meeting on the above subject at the last annual ⊕ convention. One talk on "Continuous Casting of Ingots or Shapes" could not be released, but a good account of this art was printed last month (page 497).

A—Improvements in Steel Foundry Methods

Advanced Melting Methods

By G. A. Lillieqvist
Research Director
American Steel Foundries

IT IS NOT the purpose of this discussion to present a technical analysis of the principles of steel production, because such detailed information has been exceedingly well covered in the literature. It will be my endeavor to point out some of the advanced factors which cover the manufacture of steel today compared to years gone by. Naturally it will represent facts gained in our own company's operation, with which I am most familiar.

"Cast steel" should hardly be set off as a subject apart. Steel in any of its forms is initially cast. It is the subsequent methods of working the original steel which determine whether it is to be classed as cast steel, rolled steel or forged steel. Leading steel foundries have always recognized the need for quality steel and have been constantly on the alert to improve the production methods.

Early steel foundries relied principally on a specialized bessemer converter for melting the metal. Then the acid electric furnace seemed to pre-empt the field. Now the openhearth furnace is relied upon for important tonnages.

In the openhearth process, furnaces are equipped with the latest recording devices for control, rendering the production of molten metal almost automatic. While the human element will never be entirely eliminated, operations can be duplicated with amazing precision, errors in human judgment being reduced to a minimum by the mechanical controls. The basic openhearth has entered the field of miscellaneous castings, and numerous experiments were required to find the best method of producing the type of metal required, and then maintaining that quality throughout the extended pouring time required for that particular class of work.

Slag conditions were studied carefully, and finally the correct amount of slag required on top of the ladle during the pouring period and the right consistency of this slag were arrived at, and many difficulties due to stopper and ladle refractory erosion were cut to a minimum.

The metal was given the same consideration. In the furnace the metal was watched very carefully to determine what could be done to reduce phosphorus and sulphur to a minimum and maintain that condition until tapping time. The drop in silicon and subsequent rise in phosphorus during the pouring time was reduced to a minimum, due to the perfection of the slag.

Manganese ore in the charge was considered a necessity in order to carry a high residual manganese (thought to aid high fluidity and clean steel). We have been able to eliminate manganese ore in our charge, and find that our metal is as fluid and clean as before. Another modification applies to the 15% ferrosilicon block 15 to 20 min. before tapping. This had a tendency to drive some phosphorus back into the metal. With the help of the "Carbanalyzer", and a careful check of carbon and manganese content of the bath just prior to tapping, we were enabled to meet our chemical requirements without the ferrosilicon block. This resulted not only in a lower phosphorus content, but also a substantial saving in money and alloys. Furthermore there is less chance of absorbing gases such as hydrogen and nitrogen. Since this new practice has been started, the foundry has reported that the steel pours much better.

Different methods of deoxidation with aluminum were tried. We finally arrived at the method of adding aluminum shot directly to the stream as it leaves the furnace. This appears to be the most efficient method for effecting the greatest recovery. Such experimentation enables us to obtain the proper type of inclusions necessary for the best physical results. Thus, we can produce all crystalline inclusions with a few rounded ones, and none of the elongated types.

Porosity in our castings also has been entirely eliminated.

Hydrogen gas has been the "gremlin" in the production of basic steel for miscellaneous steel castings, but by watching the vigorous boil of the metal in the furnace, careful deoxidation, dry runners and ladle refractories, and careful inspection of sand and mold conditions, we have reduced this hazard to a minimum.

Acid electric furnace operation has gone through the same thorough experimentation; likewise, improvements have been effected in the resulting steel.

All shop scrap used in the electric furnace is sent over from the basic openhearth. It contains 0.017% phosphorus and 0.020% sulphur, on the average — a charge with very low phosphorus and sulphur for the electric furnace, and correspondingly low analyses in these two elements in the finished castings.

Time does not allow me to go into extensive explanation of the varied experiments and the results derived therefrom, so I am giving you just the high spots and results obtained.

Alloy Recovery — We are also working on maximum recovery of alloys. The finishing composition of any heat is derived from alloys obtained from either one or a combination of the two following sources:

A. Alloys derived from the scrap charged.

B. Alloys added through the furnace or to the ladles.

The recovery of the various elements depends on the sources of alloy, the method of addition, the condition of the heat on addition, and the peculiarities of the element involved.

A thorough survey by analytical chemistry of our steel making methods shows our average recoveries to be as follows:

Manganese — With 80% ferromanganese added to the furnace, on heats of steel to contain less than 0.90% manganese, we will recover three-quarters of the manganese in steels of 0.30 to 0.40% carbon, and two-thirds of the manganese in steels with a carbon content of 0.10 to 0.20%. If 80% ferromanganese additions are made to the furnace when it is making high carbon steels, 1.00% or higher, the recovery drops sharply. Additions to the ladle seem to be fairly consistent at 80%, under normal conditions.

Ferrosilicon — Between 90 and 95% of the silicon is recovered in the basic openhearth, as all is added as 50% ferrosilicon in the ladle.

Chromium — Regardless of the percentages of chromium introduced through the scrap charged, a fairly consistent figure of approximately 80% of the chromium is recovered.

Molybdenum — All molybdenum added to steel is recovered, whether introduced through the scrap, or by additions to the charge, furnace or ladle of either ferromolybdenum or molybdenum oxide.

Nickel is recovered 100%, either when introduced through the charge or as pig nickel to the charge or as shot nickel to the ladle.

Aluminum — Retention of this element as metallic aluminum in the finished steel depends on the amount added and the deoxidation necessary for the aluminum to perform on the liquid steel at the time of addition. The average practice is to add 0.10% aluminum to the steel as a final deoxidizer. This addition to properly prepared steel in such a manner as to obtain maximum effectiveness yields slightly better than 30% recovery, as measured by analysis of the finished steel for metallic aluminum.

Our present trend in alloy practice is to add the so-called exothermic alloys such as "Chrom-X" and "Sil-X" to the ladle. Results so far are very encouraging. We are also experimenting with the so-called "intensifiers" ("Grainal", "Silcaz", and other trade-named substances) in order to reduce as much as possible the needs for strategic alloys.

High Strength, High Ductility Cast Steels

By Carl F. Joseph
Research Metallurgist
Saginaw Malleable Iron Division
General Motors Corp.

IN DISCUSSING high strength, high ductility cast steels, I want to clarify the requirements of such steels. In general, they fall within the U. S. Army Ordnance specification QQ-S-681, 4-B-1, 4-B-2, 4-B-3, and 4-C-1 to 4-C-4 inclusive. The class with which the writer has had considerable experience, producing many thousands of tons, is the 4-C-2 specification which has the following minimum properties:

Ultimate strength, 105,000 psi.
Yield strength, 85,000 psi.
Reduction of area, 40%
Elongation in 2 in., 18%

These steels are used for highly stressed parts for tanks, trucks, aircraft, and machine guns. Many are locally or differentially hardened for wear resistance to a minimum Brinell of 475.

In checking over the requirements necessary to produce these high property steels, I will review briefly some of the important problems and precautions necessary to consider in their manufacture. The points mentioned apply to the operation as conducted at the plant with which the writer is connected.

I. Raw Materials

A. Use of loose steel turnings up to 35% of the total charge has given satisfactory results.

B. Alloy shop scrap is usually held to a maximum of 50%.

C. Phosphorus and sulphur are kept as low as possible, under 0.035%.

D. Light rusty material is avoided if possible. Some question the harmfulness of surface rust, although a variable quantity and quality of oxide should be avoided — like any other unknown variable in metallurgical practice.

E. Busheling and baled sheet bundles have improved the properties of the resultant steel, when they have replaced turnings.

II. Melting Practice

A. Charge should be regulated to contain approximately 0.40% carbon after meltdown. This is necessary to produce a vigorous boil.

B. Common electric furnace practice is to use high tap transformer on the meltdown, and range from 210 to 240 volts on cross phase voltage. Low tap is used for the heating and refining ranges, using 110 to 160 volts cross phase voltage.

C. The bath is brought down to the desired state by addition of iron ore to provide a refining boil. Silicon and manganese are oxidized first.

D. Carry carbon down to 0.12 to 0.15%. Block heat with low silicon malleable pig iron. Take preliminary analysis.

E. Add 15 lb. silico-manganese per ton. Add additional pig iron to recarburize. Ferrochrome and ferromanganese can be added as desired.

F. Tap heat and deoxidize.

III. Deoxidation

A. For maximum physical properties it is recommended that aluminum should be avoided as a deoxidizer. This is particularly true if physical properties in the casting must approach those in the test bar. Some of the intensifiers on the market, when added to the ladle, produce castings of high physical properties, when parts of the casting are cut out and tested. For example, on steel of the following analysis, 0.34% carbon, 1.20% manganese, 0.45% silicon, 0.32% molybdenum, 0.70% copper, 0.04% sulphur and 0.04% phosphorus, casts were made with 2 lb. aluminum per ton, and also with 2 lb. per ton of a standard intensifier. The properties listed in the table at the bottom of this column were obtained.

Microstructure — Inclusions must not be gathered at the grain boundaries, but must be uniformly distributed in globular form. In general, high reduction of area is obtained with special intensifiers, rather than with aluminum, because of their tendency to form globular inclusions. The precipitation of a chain type of inclusion occurring at the grain boundaries does not affect the ultimate and yield strength appreciably, but will reduce the elongation and especially the reduction of area. This chain type of inclusion can be eliminated by careful attention to the melting practice, particularly slagging and deoxidation. Keep slag from becoming viscous when tapering off the heat, prior to kill; fluid slag is necessary to absorb inclusions. Proper use of lime in slag

Improvement in Physicals

	Aluminum Treated	"Intensifier" Treated
Ultimate strength	111,250 psi.	113,000 psi.
Yield strength	88,600 psi.	91,525 psi.
Reduction of area	26.0%	53.7%
Elongation in 2 in.	16.5%	22.0%
Brinell hardness	255	255

makes this control possible. Analysis of the slag should approximate the following for good results: FeO 10 to 14%, MnO 12 to 16%, CaO 7 to 10%, SiO_2 55 to 60%.

Composition of the steel has little or nothing to do with low ductility, except as the alloys may affect the refining or deoxidation practice. High strength and high ductility steels can be produced with 0.30 to 0.40% carbon and 1.30 to 1.60% manganese. Good melting technique is all that is required. In general, molybdenum, copper, nickel, and chromium are used together or separately to guarantee the best properties. Two of the ranges used at our plant at times were as follows:

	Range A	Range B
Carbon	0.30 to 0.40%	0.26 to 0.36%
Manganese	1.10 to 1.30	0.90 to 1.20
Molybdenum	0.25 to 0.30	—
Copper	0.60 to 0.80	0.80 to 1.00
Nickel	—	0.50 to 0.70
Chromium	—	0.40 to 0.60

Heat Treating—In producing the highest property steels, all three steps of the heat treatment must be carefully carried out.

Normalizing should be between 1700 and 1750° F., not less than 3 hr. at heat.

Liquid quenching of steels of the above compositions should be from 1550 to 1600° F., soaking at least 1 hr. per in. of cross section. The quench should be well circulated. A drastic quench definitely increases yield strength and reduction of area of tests cut from heavy castings.

The draw operation is best conducted in recirculating type furnaces, and preferably 3 hr. or more at heat, which is usually between 1150 and 1275° F., depending on the hardness desired.

In conclusion, we have ample experience back of our contention that care in selection of raw material, expert supervision of melting and deoxidation, and correct additions will do more to improve actual properties in the castings than a lavish use of alloys.

B — High Strength Cast Iron

By G. L. Richter
Metallurgist
Farrel-Birmingham Co.

WHEN ONE ATTEMPTS to discuss a field so broad as high strength cast iron in so short a time, one hardly knows where to begin. Volumes have been written on the subject in the last 20 years, but much of the information contained therein is already obsolete, due to the rapid progress made in the cast iron field. It was only a few years ago that several prominent metallurgists recommended that the cast iron industry could best be served by destroying all the handbooks published prior to 1932. In a similar way, it is certain that progress in the field of cast iron would be more rapid today if old ideas about cast iron could be forgotten, both by foundrymen and by their customers.

Today, the average layman (and unfortunately many an engineer) thinks of cast iron as a soft, brittle material that can be used for sewer covers and sash weights. Few think of it as a reliable engineering material with definite physical properties that are reproducible. Many engineers think in terms of steel alone, and the reason for this is probably that the cast iron foundry was the last to profit by adopting scientific methods whereas his competitor, the steel foundry, was more receptive to these advances. While cast iron was losing in popularity, cast and wrought steel was forging ahead, along with the science of heat treating, alloying and welding. However in the last 10 years the cast iron industry has belatedly profited by the adoption of scientific methods, so that today high strength iron is supplanting steel in many applications.

In 1930 the American Society for Testing Materials' specification for gray iron called for three classes, varying in tensile strength from 18,000 to 24,000 psi., whereas in 1943 this specification calls for seven classes of iron varying from 20,000 to 60,000. Today 60,000 psi. tensile irons are being made in routine production, and for special requirements 80,000 psi. tensile irons have been made. *That* can well be called progress!

It should be noted that under the term "high strength irons" we class all irons that are made by a controlled process to achieve specific physical properties. Nominally, these irons should have a tensile strength in excess of 50,000 psi., but corrosion resisting, heat resisting or wear resisting irons may not always be so strong. It should also be noted that such names as "semi-steel", "pearlitic iron", "high duty iron", and many others indicate nothing unless supported by a set of physical properties.

Improvement in gray iron castings has been due, by and large, to three factors:

1. Improvement in melting practices, as well

as in all features of molding, especially gating and risering practice.

2. Use of processing agents and alloys.
3. Heat treatment.

A typical high strength iron will exhibit the following physical properties in a bar 1.2 in. diameter:

Tensile strength	55,000 psi.
Modulus of elasticity	23,000,000
Compressive strength	200,000
Fatigue strength	25,000
Shear strength	over 55,000

In heat treated condition the tensile strength may be increased to 75,000 psi. and the hardness to 500 Brinell.

The ability of gray iron to dampen vibration has been recognized for some time but full use has not been made of this property. Ordinary gray iron has good damping characteristics but its usefulness is limited by its low strength. Steel has high strength but has a low ability to absorb vibration. High strength iron, on the other hand, combines the dual characteristics of cast iron and steel in maintaining excellent damping properties at high stress ranges.

In this respect it was found a few years ago by a European investigator that crankshafts made of a steel having a 150,000-psi. tensile strength failed at about the same working load as did crankshafts made of high strength iron having a tensile strength of only 50,000 psi. Failure of the steel crankshafts was of course due to built-up stress concentrations that the steel could not accommodate even though it did have a high strength, whereas in the high strength iron crankshafts the stresses never built up to a high value.

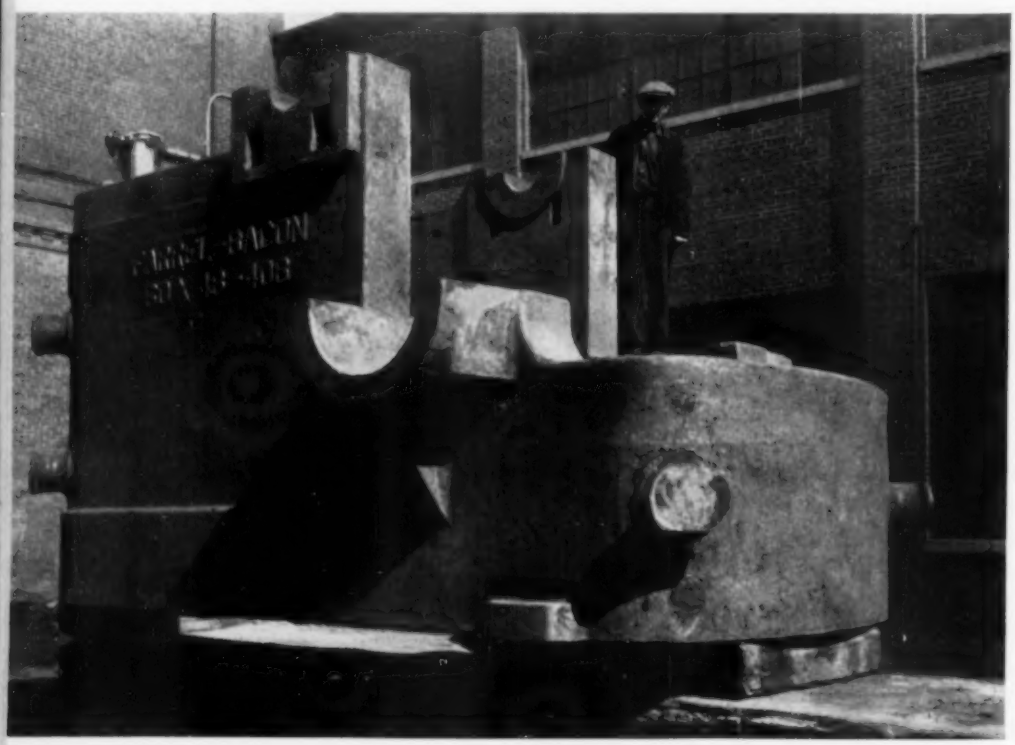
Another property of high strength iron that is many times overlooked is its good torsional strength, this value being in excess of its tensile strength. This, combined with the excellent vibration damping capacity, makes it an ideal material for rotating parts taking a twisting load.

The ability of high strength iron to carry occasional overloads with greater safety than steel, due to its freedom from notch sensitivity, is another property that should be noted.

The tremendous progress made in increasing the properties of cast iron has come from a better understanding of the physical structure of the metal with particular emphasis on the size and distribution of the graphite. (Adjoining micrographs indicate the improvement made in structure in the last 15 years.) To be sure the chemical analysis is still important, but the mere analysis obviously does not determine the physical constitution. In the foundry, chemical analysis is a major factor in establishing operating control, this being fundamental to the production of high strength iron. But there are a number of ways to produce favorable graphite structures, among them being the use of special processing agents, use of alloys, and (when melting in the electric furnace) superheating. However, it is probable that the majority of high strength iron is made in the cupola, and there is some basis for feeling that the cupola, when properly operated, produces a better graphite structure than some other melting units do. The cupola also possesses certain economic advantages.

It is readily conceded that the production of a 76,000-psi. iron without alloys, as indicated in the third micrograph, is not as yet a routine matter, but it

70-Ton Crusher Frame. Processed iron with 63,000 psi. tensile on 1.2-in. round bar. A permanent refutation of the superstition that heavy sections are full of shrinkage cavities



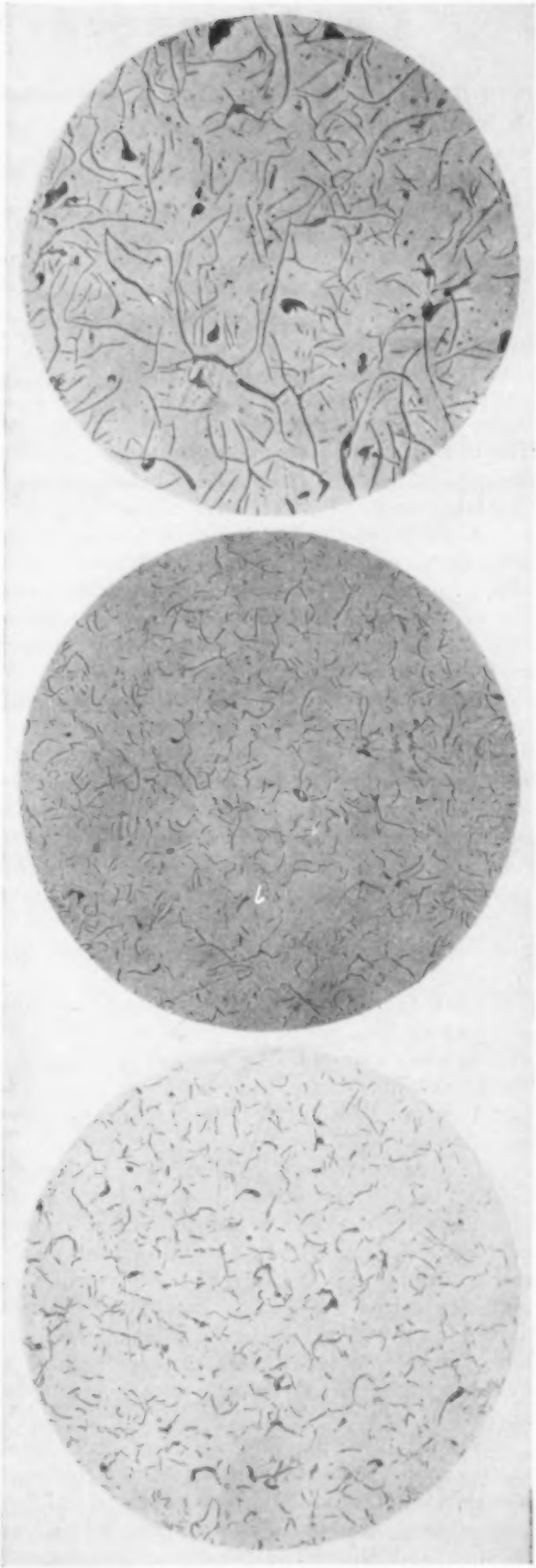
does serve to indicate what may be just beyond the horizon after a few elusive variables are brought under control. It should be noted that the carbon on this iron was 2.93%, by way of indicating that it does not require an abnormally low carbon to produce these irons.

It might be well to introduce a note of caution as regards manufacture: Unless a foundry has a high quality sand and molding practice to accommodate the high pouring temperature necessary to obtain good physical properties in the finished casting, that foundry is not going to make a high strength iron. It is almost a truism to say that high strength iron and a high class foundry go hand in hand.

High strength iron has found a wide application in war products, where it has replaced much critical or non-obtainable materials. A brief survey of some of these, where processed high strength irons have given the same or better service, is as follows:

Quenching Dies, used for rigidly holding steel airplane propeller blades to prevent distortion during quenching. Cast accurately to size and shape. Replaces steel. *Stoker Screw Castings* from 10 to 15 ft. long, for handling abrasive materials like coke. More satisfactory than nickel-chromium steel. *Recuperator Tubes* for an oil-fired rotary furnace. Replaces malleable iron and increases life by 500%. *Hydrogen Cylinder Heads* to withstand a pressure of 2000 psi. *Sulphur Distillation Retorts* formerly made of Krupp steel (high nickel-chromium). Used in production of carbon bisulphide and subjected to a working temperature of 1280° F. *Spindles, for Lathes and Grinders,* weighing over 1000 lb., formerly made of steel. *Mobile Gun Wheel Centers* formerly of steel. *Wheel Tires for Mobile Cranes* formerly made of steel. *Crankshafts for Diesel Engines and Compressors* with the main bearings lightened by cores. Cast with cored-out oil passages for lubrication system. Replaces steel. *Ship Propellers,* 5 to 18 ft. diameter, for use in both fresh and sea water. Replaces bronze. *Tool Shanks and Cast Milling Cutter Bodies* for use with brazed-on carbide tips. Higher speeds can be used and better finishes obtained. Lower vibration. *Shell Nosing Dies.* High strength iron has been widely applied. In certain shops it has out-performed the hot die steels three to one.

It is felt that these few examples will show the versatility of these high duty irons and the reason why engineers can now design with confidence when using them.



Unetched Micrographs of Cast Iron at 50 Diameters. Top: Cast iron of 1930 vintage, tensile strength 20,000 psi. Middle: Processed, un-alloyed high strength iron of 1943 vintage, tensile strength 59,600 psi. on 1.2-in. diameter A.S.T.M. test bar. Bottom: Processed, un-alloyed iron (1943 vintage) of 76,000 psi. strength, a heat for a 5-ton casting with sections 1 to 8 in. thick

C — Advanced Casting Methods

Centrifugal Casting

By Chas. K. Donoho
Metallurgist
American Cast Iron Pipe Co.

THERE ARE THREE rather distinct types of centrifugal casting in commercial use:

In one type, called "centrifuging", the molds forming the useful castings are positioned near the periphery of a revolving table. The metal is poured into a gate at the center axis and is fed into the molds by radial sprues.

A second type, called "semi-centrifugal" casting, is used to make wheel or disk-shaped parts. The casting is spun about its own axis, gated at the center, and the centrifugal force causes "pressure feeding" to the outer rim section.

A third type, which may be termed "true centrifugal casting", is employed to produce tubular or generally cylindrical parts. The casting is spun about its own axis rapidly enough that the centrifugal force shapes the interior cavity of the casting without a center core.

In the first two types centrifugal force is used merely to provide liquid pressure. However, pressure due to centrifugal force differs from pressure produced by other methods in that it is selective in its action, the heavier components being thrown outward with greater force than the lighter dross and non-metallics. The economy of these centrifugal pressure casting methods derives from the elimination of risers and increased soundness and density of the resulting product.

Centrifuged and semi-centrifugal castings are usually spun about a vertical axis. In producing wheels or gears by vertical spinning the center section, where the shrinkage and non-metallics are concentrated, is bored out in the finishing operation.

In true centrifugal casting more is accomplished by use of centrifugal force but we are also more restricted as to shape. When a mold partially filled with molten metal is spun about the horizontal axis the interior cavity formed is perfectly cylindrical and is exactly determined by the volume of metal and the mold dimensions. Since most true centrifugal castings require a cylindrical interior, spinning is usually about the horizontal axis.

Briefly, the chief advantages of centrifugal castings are: Sounder, denser, cleaner castings; higher yields; elimination of cores; simplified inspection. Disadvantages are: Limitations as to sizes and shapes adaptable to the process; expense of installing and maintaining spinning machines; increased difficulty of changing equipment to make a variety of castings.

Molds — The true centrifugal process is best adapted to the mass production of large quantities of identical castings and since this is also one of the conditions which make "permanent mold" processes economical, it is not surprising to find the two processes combined. The choice of the mold type, whether metal or sand, depends upon a number of factors which must be considered before tooling up to make a new design of castings. In general, the conditions favorable to the use of metal molds are: *(a)* A very large quantity of identical castings is to be made; *(b)* the outside contour of the casting is simple enough so that it can be readily slipped out of the mold; *(c)* a fast cooling rate from the outside inward is desirable, with attendant fine grain.

Centrifugal casting in sand lined molds is preferred *(a)* where the metal must flow a relatively long distance over the mold surface; *(b)* where the shape of the casting is such that the mold must be broken down in order to remove the solid casting; *(c)* where a relatively uniform cooling rate through a thick section is desirable.

In addition to sand and metal molds, graphite molds have been used to some extent, chiefly in the non-ferrous field.

Metals Cast — First among the metals currently cast centrifugally is gray cast iron, of which there is produced a large tonnage of cast iron pipe in lengths of 16, 18, and 20 ft. and in diameters up to 48 in.

Bronzes and brasses are cast into numerous types and sizes of bearings, bushings and sleeves, by several centrifugal methods.

Steel — both alloy and carbon — is also cast. In this field there has been a rapid development since the war began.

Aluminum has been cast centrifugally and at least some experiments made with magnesium. In these lighter metals, however, one of the chief benefits of centrifugal casting may be lost since the slag and oxides formed are nearly the same density as the metal, and consequently will not be separated as effectively by centrifugal force.

Cast Steel — Centrifugally cast steel, until a few years ago, was largely confined to the Water-

town Arsenal's cast gun barrels, a few heat and corrosion resisting alloy tubes, and gears cast by the semi-centrifugal method. Recent war use of centrifugally cast steel parts to replace forgings has given rise to the term "liquid forging", which applies to this process particularly when metal molds are used, because of the similarity between the metal molds and forging dies. Although there is always an inherent difference between a cast structure and a forged structure, the absence of the usual casting defects (such as blowholes, shrinkage, and slag pockets) makes for a higher degree of uniformity in true centrifugal castings than in most static castings.

Centrifugal castings have replaced forgings in many instances not only because of the shortage of forging capacity, but because some shapes can be more economically produced.

The cast cylinder barrel for radial air-cooled engines is one interesting recent development. This is a true centrifugal casting made in a two-part metal mold spinning about the horizontal axis. A carefully weighed amount of molten alloy steel is poured entirely into the spinning mold, and forms within a few seconds the desired part. Other parts made similarly are bogie hubs and idler hubs for tanks. A number of tubular alloy landing gear parts for bombers are made similarly, and are later heat treated to 170,000 psi. minimum tensile strength.

Parts produced by the semi-centrifugal method (sand molds spinning about the vertical axis) are gears, engine flywheels, track roller rims — to mention only a few.

Longer tubular steel parts are made by true centrifugal casting in sand-lined molds up to 16 ft. in length and 50 in. diameter. These include propeller shafting for naval vessels, hawse pipe, chain pipe for merchant ships, hydraulic cylinders, bearings and liners.

For those shapes which are adaptable to the method, centrifugal casting is an efficient process for mass production of useful engineering parts directly from molten metal.

From the John W. Higgins Collection
(Worcester Pressed Steel Co.)

Pressure Molded Die Castings

By David Basch
Schenectady Works Laboratory
General Electric Co.

IN THE PAST die castings were used largely where it was a matter of low cost, minimum machining, pleasing appearance and high speed of production. They were never recommended for any structurally responsible parts.

There is, however, no basic and insurmountable limitation inherent in the die casting principle which would rule out the possibility of obtaining structures and properties good enough and uniform enough to enter the field of mechanically responsible applications, like the best grade of sand castings or permanent mold castings. It is only a matter of using proper machinery, intelligent die design, careful control of casting technique, metallurgical supervision, and strict quality control in the inspection department.

As to machines, the prime considerations for success are:

1. Molten metal must not be sprayed in finely divided form into the die, thus preventing the oxidation of individual metal particles as they enter the die, and the inclusion of air into the casting itself. In other words, a continuous stream of liquid must enter the mold, rather than a spray or mist.

2. Sufficiently high pressure must be provided, *after the die is filled,* so as to force reserve metal from the gate into the interdendritic shrinkage of the metal in the die.

3. Metal in the gate must be kept at a temperature above the liquidus of the composition, so the liquid metal forced into the interdendritic shrinkages has not segregated.

4. Dies should be so vented that air is given a chance to get out without being trapped.

5. Provide sufficient locking pressure on the dies to prevent their opening under the tremendous metal pressure.

As to the other items mentioned in my second paragraph, intelligent die design implies effective gating, and other details to insure proper sequence of solidification, complete feeding of all parts of the casting and effective venting.

Casting control involves the determination and maintenance of best die and metal temperature, speed of operation, die maintenance, lubrication of moving members, and keeping the metal clean.

Metallurgical control should insure proper die steels and their heat treatment, check all incoming material, control the composition of the metal and the castings, see that gates and sprues are properly utilized, attend to the purification of the melt, and perform all testing, such as corrosion testing, mechanical testing, X-ray testing, spectrographic control and the making of essential photomicrographs.

Quality control involves: *(a)* Control on the floor — a check on the maintenance of best casting practice by operator. *(b)* Check *before shipment,* to make sure that all acceptance requirements are met as to composition of castings, quality of surface before and after machining, the making of X-rays, performance of specified end-use breakdown tests, and measurement of tolerances and general dimensions. *(c)* Making sure that all customers' complaints are transmitted to the casting and metallurgical departments and taken care of.

In the past, these simple requirements have been frequently overlooked — or, for the sake of keeping cost low and competitive, omitted. Considering the product which resulted from previous practices, it is not surprising that it was so unattractive to the structural engineer.

At the beginning of the war, when conservationists urged the greater use of die castings (since they constitute the shortest route from the raw material to the finished product with the greatest possible saving in strategic material, man- and machine-hours), the Armed Forces definitely and emphatically refused to employ them in critical applications where failure might endanger the soldier or disrupt important operations. However, when new specifications were drawn up which insured the effective application of all the production and control requirements enumerated above, and which instituted rigorous acceptance standards so as to safeguard quality and uniformity, their reaction was much more favorable.

In the past, Air Corps specifications did not permit any kind of die castings for a structurally responsible part. Now the new specifications, which have been drawn up by the Air Corps and a committee of the American Society for Testing Materials with the benevolent assistance of War Production Board's experts, allow the use of so-called "pressure molded castings". This special and distinctive new name was coined by the Air Corps to prevent competitive entanglements with commercial die castings. Generally, such "pressure molded castings" are permitted for parts in which the design load is more than about 40% of the tensile strength of the alloy, and up to about the yield stress of the material.

Forgings and stampings are still *preferred* to any kind of casting (sand, permanent mold, pressure mold) but castings of the new species are *permissible.*

At the instigation of the War Production Board and the Armed Forces, the die casters were acquainted with the new specifications and asked whether they would accept orders under them. Those who expressed their willingness were inspected by a committee appointed by the WPB's Die Casting Industry Advisory Committee as to their equipment in casting and machine shop and laboratory, personnel, technique, experience, ability to meet all requirements and quality control. Those plants which passed inspection are being certified by WPB to the Armed Forces as recommended vendors. A considerable number of die casters has been found acceptable so that there will be plenty of manufacturing capacity available.

It is my opinion, shared by many die casters, that pressure molded castings after the war will open up to the industry many fields hitherto closed, and thus make up for that part of the business which will inevitably be lost to plastics, powder metals, plaster mold castings, and various other newcomers in the field of low cost production. There will undoubtedly still be heavy production in the so-called commercial die castings, where cost and general appearance are the principal considerations, but as die casters handle more and more of the pressure molded casting line the general level of die casting quality is bound to rise.

A fascinating story, taken from a statement before the Truman Committee, March 6, recounts the efforts made by one pioneering company to reclaim a chemical by-product, and to learn how to alloy, fabricate and use a metal which suddenly became one of the war's most necessary munitions

A Brief History of Magnesium in America

WHEN the first World War broke out in 1914, all the magnesium used in the United States was imported from Germany. The market for metal — which sold at $1.65 per lb. — was trifling. It had no structural use and was principally bought by the makers of fireworks and flashlight powders. In powder form it flared brilliantly. Its other use was as a deoxidizer in some chemical reactions.

American chemists knew quite a good deal about magnesium in a laboratory way but nothing at all about making it commercially — and there was no reason why they should, because consumption was so small.

Magnesium had been known for a long time. In 1808 Sir Humphrey Davy found that "Epsom salt" contained a new metal which he called *magnium*, and he produced an amalgam of it. (There was a deal of confusion in nomenclature and the word "magnesium" was applied to the metal which we now know as manganese.) In 1830, Bussy brought out the first pure metal by effusion. Some commercial production was tried in tiny plants in England and France which were not much more than laboratories and also for a while by a concern in Boston.

The modern industry was really begun by Bunsen in 1852 when he derived pure magnesium by the electrolysis of fused magnesium chloride in a porcelain crucible. The German chemists, working on ways to utilize to the utmost the salt deposits at Strassfurt, from which so much of the German chemical industry has sprung, found that they could use it in a modification of the Bunsen process. In 1886, the first electrolytic plant began operations at Hemelingen near Bremen and some ten years later the Chemische Fabrik Griesheim Elektron began operating at Bitterfeld, trade-marked the product "Elektron" and began intensively to develop alloys and methods of fabrication.

Magnesium metal has a strong affinity for oxygen and, although this is a most valuable quality in a flare, it is anything but valuable in a structural metal. That is why it was dismissed — even by our own aircraft builders up to 1939 — for not only was it very brittle but also when exposed to the air it corroded and became magnesium oxide, and when heated for casting it did the same thing at a more rapid rate and either caught fire or the casting became a spongy mass of no value. The Germans learned how to alloy and to cast magnesium with aluminum, zinc and other metals, and these "Elektrons" were reasonably strong and very light. They were the first to recognize that production and fabrication were separate subjects requiring separate techniques and that no matter how cheaply the pure metal was produced it was well-nigh worthless unless it could be alloyed and fabricated, and that the bottleneck to its greater use was in finding cheap methods of fabrication.

When the 1914 blockade shut off the supply of magnesium for tracer bullets, flares and flash-

By Willard H. Dow
President, Dow Chemical Co.
Midland, Mich.

light powders, the price rose to above $5 a pound. Since no great manufacturing skill is required to produce at such prices, several concerns which had ample power and some experience in electrolysis went into manufacturing. The first of these was General Electric Co. at Schenectady, early in 1915, quickly followed by Norton Laboratories at Nashua, N. H., and Lockport, N. Y.; the Electric Reduction Co. in New York City; Aviation Materials Corp. and American Magnesium Corp., both at Niagara Falls; Magnesium Manufacturing Corp. at Rumford, Maine; and Shawinigan Electro Metals Co. Ltd. in Canada. The acute American pinch was the lack of magnesium as a deoxidizer of nickel.

The Dow Chemical Co. had magnesium chloride in the Michigan brines they were working in large volume for bromine and bleach, and in mid-1916 decided to make the metal and began experimenting. The first step was to get a magnesium chloride free from water. In crystal form it contains about half its weight of water which cannot be taken out by direct heating because the chloride oxidizes with its own water of crystallization. The group finally worked out a method of evaporating a solution of ammonium chloride and magnesium chloride and crystallizing out a double salt which could be air dried and then fused to obtain a clear, water-free magnesium chloride. This was known as the sal-ammoniac process and it could be organized on an engineering basis.

First Reduction Pot

The next step was to get out the magnesium. The Dow group of experimenters made a small, rectangular box of welded boiler plate, lined it with slabs of soapstone and divided it into two compartments with a soapstone partition that did not extend to the bottom. An iron plate was fastened in one compartment and a graphite rod in the other. These electrodes were connected with a low voltage, direct current generator and the whole was covered with soapstone slabs. This cell was heated over a brick arch, molten magnesium chloride poured in and the current turned on during one of the hottest afternoons that Midland had ever known. Soon little globules of metal began to float on the surface of the bath. The group stood by all the night, anxiously watching and breathing in quantities of chlorine gas. They found to their surprise that the electric current was of itself sufficient to keep the salt bath molten and not once during the night did they have to make any adustments. In the morning they had a 1-lb. cake of metallic magnesium. That beginning was on July 20, 1916.

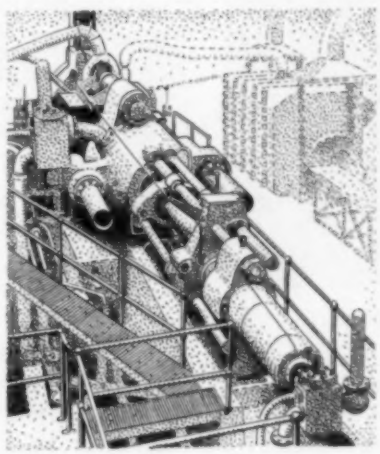
The group kept right on with this little cell. They learned that adding common salt to the magnesium chloride lowered its melting point and that a little fluorspar helped the metal to coalesce. Also they discovered, when they tried to melt down the metal, that the liquid of the fused cell bath made the best flux. This discovery was the basis of the present process for melting magnesium and reclaiming scrap.

The next step was to a cell six times as large, from which to learn the essentials of engineering to go on a production basis. The appropriation made on August 17 was $10,000. This cell took a 500-amp., low voltage current; it operated reasonably well and on good days produced a dozen pounds of magnesium. But the bath would freeze unless the proportions of magnesium chloride and common salt were held within close limits. Chlorine gas sometimes drove the operators out of the room and the magnesium chloride volatilized out of the cells and condensed on walls and chairs, as well as the clothing of the operators, which became covered with a dirty, slimy coating of magnesium chloride.

Nevertheless the unit was kept going and in the winter of 1916-17 the group decided they knew enough to go into production. Work started on a $50,000 plant which was to be a real plant, with a series of 25 cells which would turn out a ton every working day. This, of course, called for an extensive equipment for deriving more magnesium chloride from the brine and all the paraphernalia required to produce anhydrous magnesium chloride in quantity. The cells were each to hold from 300 to 400 lb. of molten salt kept hot by oil burners. On an autumn day in 1917, the plant was finished and ready to go into production. There was some trouble in getting all the cells filled with molten salt, but finally they were all filled and the current turned on. Then things began to happen. Some of the cells became too hot and others, because a proper means for getting the metal out had not been devised, were short-circuited by an accumulation of metal, while still other cells, for reasons best known to themselves, chose to freeze up. Chlorine gas leaked out and the workers could scarcely stay in the room. Finally a few cell pot castings cracked and the liquid magnesium flowed out over the floor but fortunately did not catch fire. Within 48 hr. the plant had to be closed down as a failure.

Dr. Herbert Dow, my father, took the loss casually, said he thought that they all knew enough now to make another and better cell. So this time the cell was a big cast steel pot which

served as a cathode. Over this was suspended a large graphite anode and the lining surrounding the anode formed a chamber for collecting the chlorine gas. The group had also found that the magnesium chloride did not have to be absolutely free from water, so they partially dehydrated it and mixed it with an equal weight of sodium chloride and melted the mixture at a controlled temperature. This cell worked. It produced 50 to 60 lb. of magnesium a day for weeks at a time. The catch was in the accumulation of sodium chloride in the cell, and the success of the operation depended largely on the skill and the judgment of the operator. Sixteen other units were gradually installed, but on Feb. 1, 1920, after the plant had been in apparently successful operation for six weeks, one of the pots broke, the molten bath gushed out over the floor, set fire to the building, and in almost no time the whole plant was ablaze with a new kind of fire that nobody knew how to put out. The only salvage, curiously enough, was a pile of magnesium ingots that had been stacked on the floor.



The company had sold 3852 lb. of metal in 1918 and 859 lb. in 1919. The loss was over $60,000. Of the several magnesium metal producers that had started business in the war period, by 1920 only the American Magnesium Corp. at Niagara Falls and Dow at Midland remained. Nevertheless, Dr. Dow and his group had learned so much that they simply had to build another plant. This time they set up only four-cell units — in order to do some testing before going further. The mixing of magnesium and sodium chlorides had proved as unsatisfactory as the sal-ammoniac method but for different reasons, and all knew by now that the key to producing metal cheaply and satisfactorily lay in getting the right magnesium chloride.

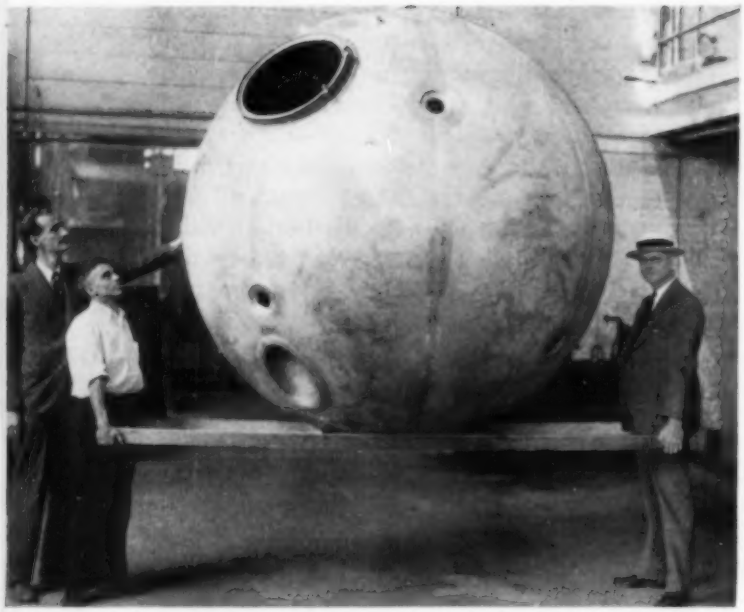
The new cells, which mechanically were much improved, used an anhydrous magnesium chloride obtained by an ingenious process in which the hydrated salt was partly dried in the air and then further dried, but not completely, in an atmosphere of hydrochloric acid gas. A lot of brilliant work went into this research. The process developed is fundamentally the same as used today and was one of the most important factors in establishing the magnesium industry. This plant was operated satisfactorily, but, as the depression settled upon the country late in 1920, there seemed just no point in piling up metal for which there were no customers. The plant shut down and did not reopen until 1922.

During these years (1916-1922) our men had started with nothing except laboratory knowledge and, devising ways and means as they went along, at no step did they have a situation which could be covered by a basic patent. There were no basic patents in the magnesium industry. Anyone who chose could enter.

During the calendar year 1922 we turned out 59,179 lb. of magnesium. But while in previous years we had sold all but a trifling amount as ingots, in 1922 we sold magnesium alloys in the form of castings, despite our intention to make metal and to sell it to processors who would do their own alloying and fabricating. The American Magnesium Corp., the only remaining American competitor in the production of magnesium, had gone into both alloys and fabrication. There was little hope for Dow to sell any metal unless there were processors to buy the metal. It became evident by 1918 that the processors would not grow of themselves and would therefore have to be grown. We knew nothing about making either alloys or castings and had access to no body of knowledge. Therefore in 1918 Dr. Dow opened a little metallurgical laboratory to develop and test alloys and a little foundry and shop for casting and machining — all to accumulate knowledge so as to teach others how to go into business. We ran into some patents and had to work out our own alloys and we called these alloys "Dowmetal".

The I. G. work, sponsored by the post-war chemical trust, the German I. G. Farben, largely centered around alloys of magnesium with aluminum and zinc, while the American Magnesium Corp.'s centered around alloys of magnesium with aluminum, and Dow's around alloys of magnesium with manganese and aluminum. About the only advantage the I. G. had was patents covering the use of sulphur to protect the metal while being melted and cast — the sulphur taking up the oxygen that the hot magnesium would otherwise have seized. We had evolved a process which did not use sulphur and gave as good results as the German method, but it was a little more expensive.

About 1920 the Aluminum Co. of America, which had purchased American Magnesium



In 1933, the Picard-Forney Stratosphere Expedition Used a Welded Dowmetal Gondola, Shown Here During Fabrication. Jean Picard is at the far left, while the man at the right is E. O. Barstow, of Dow Chemical Co., to whom much of the credit for the development of magnesium belongs

Corp., persuaded some of the motor companies to use an aluminum alloy for pistons. We figured out that, if aluminum were good, magnesium would be better, and tried our hand at casting and machining pistons in the hope of persuading the motor manufacturers to adopt them and to do their own manufacturing — buying the metal from us. We got less than no encouragement because of the belief that if the pistons became hot enough they would burst into flame. Indeed, at Wright Field, Dr. Dow had to put a stick of metal into a pan of flaming gasoline before the army engineers could be convinced that it was even safe to have around!

There being just no way of breaking down the resistance of the motor manufacturers, we turned to the replacement business, and eventually worked up a volume of about $100,000 a year, but the cost of selling pistons was so high that the enterprise was gradually abandoned. We tried to get magnesium adopted, and with some success, for portable tools where light weight was important. But we did not gain any large customers nor develop any important structural uses. We did succeed in extending the field of pure magnesium as a deoxidizer.

The largest outlet for magnesium was for use as an alloy with aluminum. That use was taken care of by the American Magnesium Corp. But Dow steadily expanded production, jumping to 72,250 lb. a year in 1923 and to over 200,000 lb. in 1926 and steadily bringing down the price, in the hope of being able to compete on a price basis with aluminum. In 1922 it sold at $1.60, but by 1926 Dow was selling at 69¢. In every year up to 1925, Dow lost money substantially; in 1926 sales netted about 5% and in 1927 1%.

The year 1927 marked a turning point in the Dow magnesium business. It was still a very little thing, with 26 employees, and only in 1926 had the sales run above $200,000. The American Magnesium Corp. made more magnesium than Dow, using a process based on magnesium oxide. This is infusible but soluble to a certain extent in fused magnesium fluoride. There was no question but that the Dow process used less current and, with the ability to get cheap magnesium chloride, it was not only cheaper but made a purer product. For this and perhaps other reasons, American Magnesium Corp. chose to stop producing magnesium and Dow was left in 1927 as the country's sole producer — in effect, presented with a monopoly by default, the same kind of monopoly which comes as a matter of course when anyone makes a thing better and cheaper than anyone else. The Magnesium Corp.'s business gave us a sufficient backlog to warrant enlarging production and going forward with price reductions and extending facilities, so in 1927 we began building on a program to make 1200 lb. a day.

Dr. Dow had an even larger vision, stating in 1928, "Metallic magnesium is now being taken up by aviation engineers the world over and promises to be one of the most important lines Dow has ever developed. That research work has cost more than any other research work we have ever undertaken." At the annual meeting next year he said: "Twelve large airplane motors are now under construction in which the crankcases are made of magnesium. There are possibly a dozen airplanes now flying driven by magnesium propellers, and all of them, so far as we can ascertain, are giving entire satisfaction." How long it took to achieve these rosy hopes would constitute a separate and lengthy story.

In 1930, we organized a sales division to handle only magnesium and its products. This came about through an exhibition of Dowmetal at the National Air Show in Detroit. The Packard, the Wasp and the Hornet engines had magnesium crankcases. The show produced many inquiries and new contacts which could be handled only by specialists. However, we continued the policy of trying to teach others to fabricate, rather than adding to our own activities a metal manufacturing division. Every prospective customer involved special research. So from 1930

through 1934 the cost of sales exceeded the amount received from sales.

The important quarry was the airplane and motor car companies. We installed a squad to teach the Wright Aeronautical Co. how to make castings and did likewise with the Eclipse Aviation Co., which made airplane starters and had been buying its metal from Germany. The principal progress was with Ford Motor Co., and had us excited at prospects of an immense market. But the project never got very far and lasted only three years. Cadillac used some castings for crankcases. In the general field, the Bohn Aluminum and Brass Corp. set up a jobbing business, having become interested in the piston manufacture which Dow had abandoned. But its efforts lasted only three or four years. Wellman Bronze and Aluminum Co. of Cleveland also began a general business.

The Warner Co. made some cast Dowmetal wheels for airplanes, and Goodyear also began using them, but neither the Army nor the Navy could be induced to take any particular interest. They took no official account of the European experience with Elektron, which had been used to some extent in planes and in the Zeppelins during the first World War. By the '30s, Elektron was in general use in German airplanes. In 1930, several thousand Italian Isotta-Fraschini aircraft motors, extensively using magnesium, were in commercial operation and in 1934 the catalogue of one British firm listed 102 aircraft parts as regularly made out of magnesium alloys. An Italian air squadron, under the command of Signor Balbo, flew to America in 1933. It was found that their engine crankcases, cylinder covers, oil tanks, pump bodies and a number of other parts were made of Elektron. For some reason the progress in the United States was very slow in the aircraft industry, where price — which in other industries formed a primary obstacle — did not really count. The best we could do was to inaugurate a test program on coatings for protecting the alloys against salt water. Nevertheless, having a conviction that magnesium was bound to be the future airplane metal, we extended our program in 1932 — in the depth of the business depression — by installing an extrusion press, rolling mill and foundry at a capital outlay of $380,000.

Production had jumped from 522,099 lb. in 1928 to 1,313,853 lb. in 1929. The total was 1,160,122 lb. in 1930 and 1,660,972 lb. in 1932. But, although the sales had topped $500,000 in 1929 and nearly that in 1930, they dropped to half or less in 1931, 1932 and 1933.

That presented a serious inventory problem in these three years and also a price question, both bound up with the peculiar conditions under which magnesium is produced.

Magnesium's real competitor was aluminum. It was therefore necessary to sell near the aluminum price. But to bring the cost down, we had to have large facilities in continual production, and run the risk of being buried under an inventory.

The checkmate to our price policy for pure magnesium metal came in the fabrication of the metal for structural purposes. There never was a sufficient volume of orders to permit repetitive

One of the Cell Rooms in the Huge Dow Sea Water Plant at Freeport, Texas. Pots are mostly below floor level; brick arch covers and laminated bus bars are clearly shown. Round carbon electrodes are hung from control equipment on floor above

or mass methods. That ran the labor cost up. As wages went up, there were few corresponding improvements in facilities to offset them. So, as the price of pure magnesium went down, most of its fabrications went up.

However, the price and quality of the Dow-metals were getting it a reputation abroad in competition with Elektron. The first magnesium sale of 5000 lb. had been made to an exporter in 1928, and this opening wedge produced sales to England and France in 1929 of 114,963 lb. After a slight lag, the foreign sales jumped in 1933 to 438,974 lb., about half of which went to England and the remainder to Mexico, Germany and Russia. While our inventory on May 31, 1933, stood at 2,931,427 lb., the rush of foreign buyers drew it down to 1,494,759 lb. on May 31, 1934, and the buying orders kept coming in. In 1933, sales for the first time in Dow Chemical Co.'s history exceeded production.

The year 1935 marks the emergence of magnesium as the world got ready for war. Also in that year we began to get into big business. France, Austria, Russia and Italy all began to go into production and we again sold over 2,000,000 lb. abroad, now selling to France as well. Dollar volume of metal sales for the first time crossed the million dollar mark, jumping from $672,000 in the previous year and $273,000 in 1933. But even these large Dow operations were conducted at a small loss. In view of the trends, and our conviction that we had the cheapest production costs, we nevertheless steadily expanded at Midland and began to look around for still more production. There was a distinct limit to the capacity at Midland, as metal had to be kept in step with the other products taken from the brine. Production here rose from over 4,000,000 lb. in 1935 to over 6,500,000 lb. in 1939. Bulk of the sales was to foreign countries, against the coming of war. Germany did not buy after 1936, conserving its exchange; most went to England, Poland, Holland, Mexico and Japan. To push the metal in every possible direction in America we spent about $300,000 in intensive research between 1935 and 1939. The number of fabricators in America, because foreign nations ordering airplanes in the United States specified magnesium alloys, jumped to 17 in 1937, and to 30 in 1940.

To revert to 1937. Our faith in magnesium as a structural material was based on a conviction that a very light, strong metal must eventually find a wide use — a conviction sustained by trends in Europe. We therefore spent $650,000 to increase our cell capacity by 50%; the limit was raised by $340,000 to keep ahead of sales in 1939. By March 1940, plans were again extended to give an eventual capacity of 12,000,000 lb. per year at Midland. No exact limit of production had been established here, but during the previous decade the demand for bromine for making ethyl gasoline had grown so large that a plant for extracting it from sea water had been put into operation near Wilmington, N. C. Our expansion program for magnesium had set a goal of 24,000,000 lb. per year, so it was also logical to get half of it elsewhere.

Sea Water for "Ore"

Research into raw materials had included extraction of magnesium from various minerals. Because of our experience at Wilmington, we knew how to handle sea water, and the decision was reached that it was cheaper to pump sea water than to mine rock, provided a sea water site could be found that had cheap power and an abundant supply of limestone and salt. The Gulf of Mexico offered several such sites, and Freeport, Texas, was settled upon as the best. There is a strip of land bordered on three sides by the ocean water of Freeport Harbor, with the opportunity to dispose of the waste liquor through a canal to the Brazos River, returning the used sea water to the ocean several miles from the intake. Natural gas insured cheap power in plenty, the oyster shells at the bottom of Galveston Bay gave an inexhaustible source of limestone, while a salt dome near by could be piped for all the salt that would ever be required. In addition, sulphur and petroleum were near at hand and transportation was adequate. In view of the emergency, construction was started in April 1940, without the usual preliminary of a pilot plant.

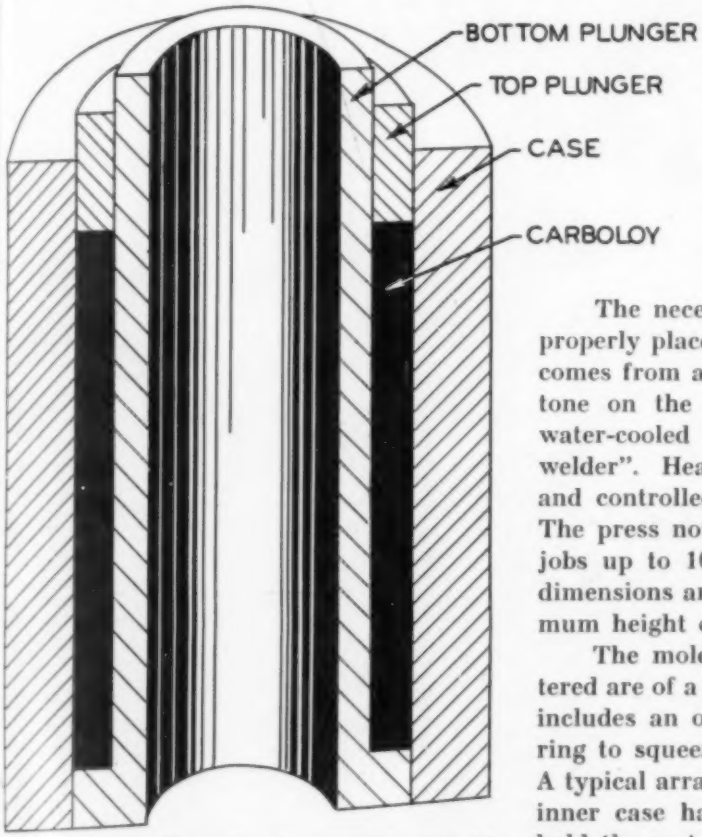
Plans for Freeport contemplated a complete chemical industry using sea water as the major raw material, just as at Midland the brine is the major raw material. Water is pumped from Freeport Harbor, at a depth of 30 ft. to avoid possible dilution by rain water, taken through a series of screens to large tanks where it meets a milk of lime. This lime, only a little while back, was oyster shell. The shells had been dredged, brought to the plant, washed, put through an enormous lime kiln and then slaked. The contents of the tank, which is called a flocculator, are kept agitated and acidity closely controlled. In it the magnesium chloride and magnesium sulphate react with the lime to become magnesium hydrate, and this settles to the bottom as a heavy sort of milk of magnesia.

The milky magnesia is drawn off into a highly ingenious filtering tank, *(See page 718)*

Large Carbide Die Nibs Formed by Hot Pressing

CEMENTED CARBIDE die nibs too large to be sintered in available furnaces — as well as special, thin-walled parts that tend to go out of round when pressed and then sintered in the regular way — have been made by Carboloy Co., Inc. of Detroit by a "hot press" method which incorporates in one single operation the three distinct processes of pressing, semi-sintering, and sintering. Pressing of metal powders into hot molds has been frequently suggested as a method of solving difficult production problems or of attaining desired properties in the finished part, but the practical difficulties have been all but insurmountable. Chief of them, of course, has been the high sintering temperatures required by most of the metal powders — and most especially by tungsten products. High temperatures can be easily attained by electrical methods, but the real problem has been to find some readily available mold materials that would simultaneously resist the high temperatures and the high pressures of compaction.

The hot pressing method of producing large carbide die nibs of excellent quality — some of which contain up to 50 lb. of carbide alone — is now proving extremely successful, so much so, in fact, that it is now believed that carbide forming dies for turning out such deep drawn articles as post-war kitchen ware and headlamp shells can be manufactured economically by hot pressing.



Cross Section of Typical Mold

The necessary heat is secured by electrical resistors properly placed to attain sintering temperature. Pressure comes from a 100-ton hydraulic press shown in the halftone on the next page. This press is equipped with water-cooled platens and is very similar to a "press-welder". Heat is supplied through a 750-kva. transformer and controlled by General Electric electronic contactors. The press now in regular operation at Carboloy handles jobs up to 100 sq.in. in cross section, although outside dimensions are limited at present to a 20-in. circle. Maximum height of work which can now be handled is 8 in.

The molds in which the parts are pressed and sintered are of a graphite-base composition. The combination includes an outer case, an inner core or plunger, and a ring to squeeze down the carbide powder between them. A typical arrangement is shown in the sketch at left. The inner case has a corresponding flange at its bottom to hold the metallic powder in. The original volume must

be carefully calculated, since the density of the finished piece depends upon how much material there is in the carbide part when the squeeze-ring on the top plunger has been brought flush with the mold-top at the end of the operation.

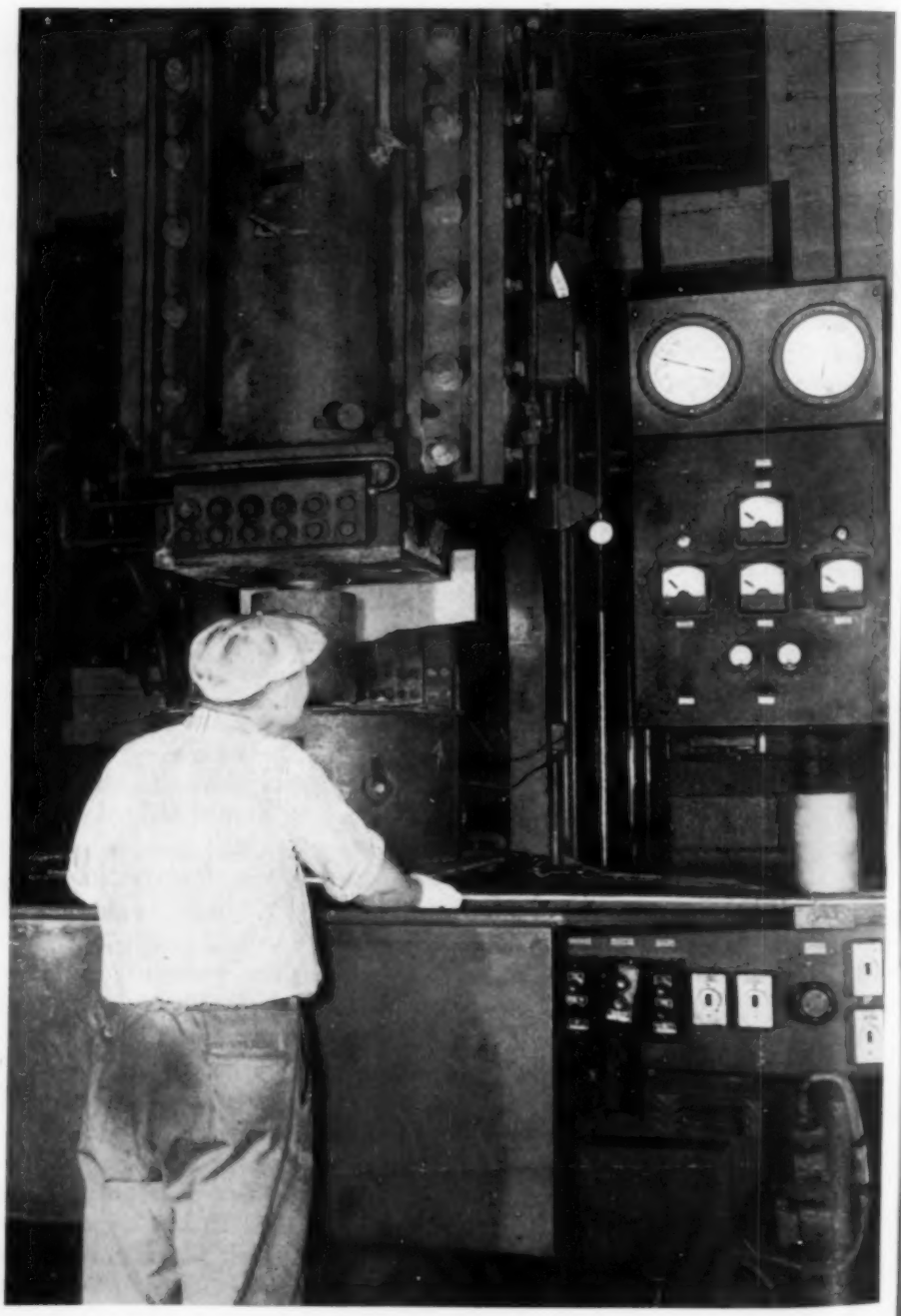
Carbide tools are used throughout in machining these graphite-base molds, since the bonding material is highly abrasive and dulls high speed steel at the outset of any cutting operation.

When fabricating the larger die nibs, the mold with its content of metal powder is often preheated in a "portable" furnace. This auxiliary heating unit has a controlled hydrogen atmosphere to protect both the graphite mold and the molybdenum resistance wires. When preheating is finished, the furnace, together with the mold containing the metal powder, is pulled from its stand-by position to a location directly underneath the platen by a convenient cable and pulley arrangement. Usually, the preheating furnace draws current during the entire process of hot pressing, so the heating operation is actually continuous — "preheating" therefore meaning "heating prior to any pressure".

Hot pressing of large die nibs is, of course, necessarily a relatively slow process to assure even heating throughout, and to limit the required current densities. During the process, two pressures are used — a "normal" pressure, and the superimposed final pressure effective as the final sintering temperature is reached. At the beginning of the operation, the pressure head travels fairly fast but slows down considerably as the compression increases. For this reason, the final ⅛ in. of movement is under the higher pressure. When sintering is completed, the part is removed from its mold. Each finished piece is checked for density and hardness.

Included among the parts which are now being produced by this method are long, thin, hollow pieces such as shell nosing dies for 90-mm. and 105-mm. shells, and tapering and casing dies for the same caliber ammunition. A very interesting item is a broaching ring for finishing aircraft engine bearings, silver lined. Rings for these broaches must be extremely thin and entirely free from porosity.

100-Ton Press, With Refractory Molds, Capable of Heating and Sintering Carbide Compact While Under Heavy Forming Pressure



While extraordinarily high-carbon films are sometimes found on carburized work, evidence is produced that this is an abnormal condition and that properly controlled furnace conditions give perfectly predictable carbons and carbon-penetrations

Maximum Carbon in Carburized Cases

A DISCREPANCY exists in the literature concerning the amount of carbon at the surface of carburized articles as affected by the temperature of carburizing. On the one hand we are told that the highest carbon cases are produced by lower carburizing temperatures, and on the other hand that the situation is diametrically opposite.

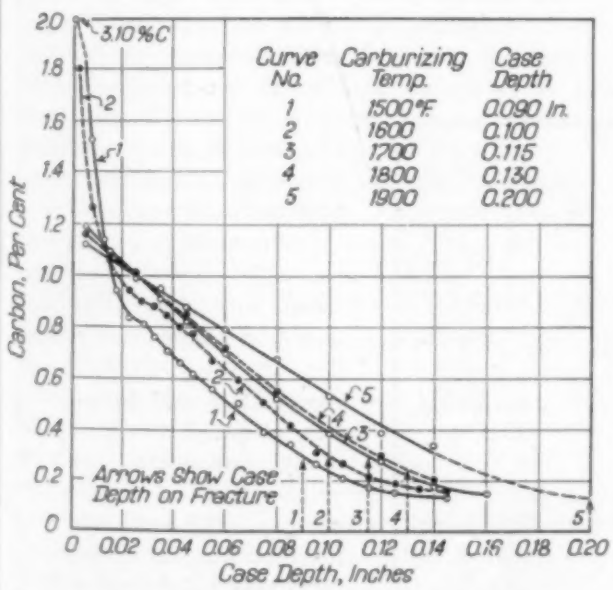


Fig. 1 — Carbon Penetration Curves, According to R. W. Schlumpf, of Samples Packed in Solid Compound and Carburized at Indicated Temperatures

For example, Fig. 1 reproduces data by R. W. Schlumpf of Hughes Tool Co. showing carbon penetration curves for five different runs on S.A.E. 3115 steel in sodium energized compound at temperatures varying by 100° between 1500 and 1900° F. This diagram was used by Harry McQuaid in his paper "A Study of the Effect of the Aluminum Addition on the Structure of a Quenched Carbon Steel" in *Transactions* for June 1937 (page 493). McQuaid says:

> "It is a well known fact to those who have made a study of the effect of carburizing temperatures on the case characteristics, that one of the effects of lowering the carburizing temperature is to increase the maximum carbon content of the hypereutectoid zone. It is often observed that a long-time carburizing at temperatures of approximately 1500° F. will result in the presence of spheroidal carbides at the surface in sufficient amount so that a chemical analysis of the first 0.005 in. of the surface will show a carbon content in excess of 3%."

Schlumpf's results were quoted by A. L. Boegehold and C. J. Tobin in their contribution to the Symposium on Carburizing (page 79) in the section where they discuss the carbon content at the surface of the case. They add this qualification: "The nature of the carburizing

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compound and the time at heat are two other factors that have a very definite influence on the carbon content at the surface of a carburized specimen. . . . .The range of variation [by variation of the composition and nature of the compound], however, is nowhere near that which is possible by variation in temperature of carburization." (Boegehold has recently informed me that "Schlumpf's results were accepted in good faith without checking them. Slow cooling would precipitate pro-eutectoid or network carbide to the grain boundaries. Since the surface of the test bar constitutes the grain boundary of all grains in the surface layer, the very surface might be a continuous layer of iron carbide with carbon content of 6.6%. If the first cut were very thin, say 0.002 in., its carbon analysis would be correspondingly high" — and, I might add, be wholly misleading as to the actual conditions existing in the steel *at the carburizing temperature.*)

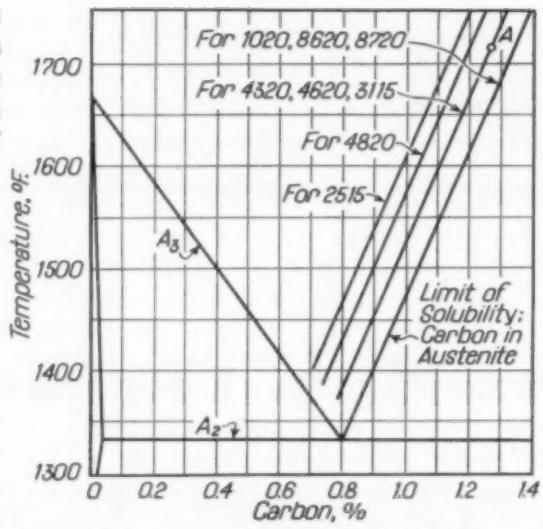


Fig. 2 — A_{cm} Lines as Determined by Surface Carbon in Steels Carburized at Various Temperatures

Now contrast with these opinions and experiences the information presented by the present writer in his article on "Case Depth" in *Metal Progress* for August 1943 and the data sheet in that same issue. Our experiments at Buick show that the carbon contents at the surface of carburized samples come fairly close to the amounts called for by the A_{cm} line of the equilibrium diagram, modified according to alloy content. Such facts are summarized in Fig. 2, and indicate of course what would be expected on theoretical grounds, namely that saturated austenite contains more carbon as the temperature increases. Reference to the article will reveal the experimental conditions. As to carburizing medium — it was a steady flow of a controlled mixture of 8 parts of natural gas, analyzing 79% CH_4, 8% C_2H_6, 4% C_3H_8 and 9% N_2, and 55 parts of "drycolene", analyzing 22.7% CO, 2.2% H_2 and 75.1% N_2. There was no CO_2 in the effluent (analyst reported 0.0% CO_2) and we have evidence that the gas established saturated austenite at the surface of the samples in all runs within 15 min. and maintained this condition thereafter. Carburized samples were air cooled.

Logs of Tests on 1.43% Carbon Toolsteel

Time	CO_2 in Effluent	Gas Fed to Retort			Remarks
		Steam★	Natural Gas†	Drycolene†	
	Bars S-3 and S-4 at 1700° F.				
11:50 A.M.	4.6	4¾	0	55	Bars S-3 and S-4 in
1:15 P.M.	4.6	4¾	0	55	
3:50 P.M.	4.9	0	0	55	Steam off
4:20 P.M.	1.5	0	12	55	Bar S-3 out‡
4:35 P.M.	0	0	4	55	Start carburizing
8:35 A.M.	0	0	4	55	Bar S-4 out
	Bars S-5 and S-6 at 1600° F.				
8:55 A.M.	..	5.0	..	55	Steam on
9:05 A.M.	11.0	0	4.0	55	Steam off
9:20 A.M.	5.8	0	12.0	55	
9:40 A.M.	1.0	0	12.0	55	
9:50 A.M.	0	5.0	0	55	Steam on
11:40 A.M.	4.7	5.0	0	55	Bars S-5 and S-6 in
12:10 P.M.	..	..	..	..	Bars at temperature
1:15 P.M.	4.7	5.0	0	55	
4:00 P.M.	4.4	0	0	55	Steam off
4:10 P.M.	2.8	..	12.0	55	Bar S-5 out
4:25 P.M.	0	..	4.0	55	Start carburizing
8:25 A.M.	0	..	..	55	Bar S-6 out

★Pressure in psi. †Metered at cu.ft. per hr. ‡Water quenched.

An endless argument might be enjoyed over the cause of these divergent results. There is of course the obvious difference in carburizers, solid vs. gaseous, although Giolitti rigorously proved long ago that solid carbon, in the absence of gas, was practically impotent as a carburizer. There may be time differences, differences in cooling rates, differences in "normality" of the steel, in its grain size and alloy or inclusion content, whether carbide is in globules or lamellae, and so on and so on. If that were not enough

it might be argued that the analysis of the first 0.005-in. cut from a carburized round might, on the one hand, be supersaturated in carbon by being in contact with a "highly energized" medium or, on the other hand, might be less than saturated because it had lost some surface carbon to the atmosphere while cooling.

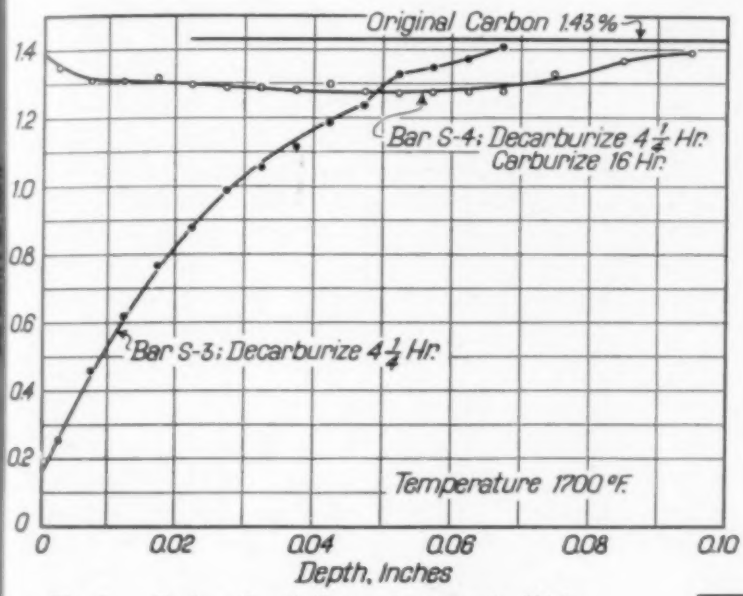


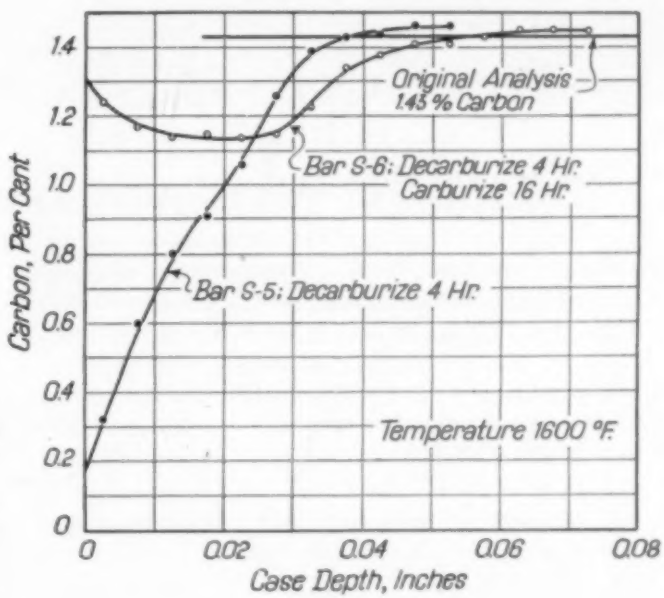
Fig. 3 — Carbon-Depth Determinations in High Carbon Steel After Decarburizing 4¼ Hr. and After Subsequent Carburization at 1700° F.

We attempted to cut through all these arguments and uncertainties by some experiments on a 1-in. bar of straight carbon toolsteel made by Vulcan Crucible Steel Co. and analyzing 1.43% carbon, 0.21% silicon, 0.29% manganese and 0.04% chromium. Figure 2 shows that this carbon content should be in approximate equilibrium with a carburizing atmosphere at about 1775° F., and should therefore be able to indicate what the A_{cm} points are at 1700 and 1600° F.

The adjoining table gives a log of the two tests, one at 1700° F. and the other at 1600. In both runs, drycolene generator gas was fed to the furnace retort at the rate of 55 cu.ft. per hr. This gas is approximately "neutral", and was made to decarburize in the first part of the heat by adding steam, and the effluent contained CO_2. After about 4 hr. the CO_2 was flushed out by natural gas, the CO_2 dropped to 0.0%, and carburization started. Turnings 0.005 in. thick were removed in succession from the heat treated specimens, analyzed for carbon, and the carbon-depth curves plotted in Fig. 3 and 4.

The carbon-depth curves for the samples after decarburization, when compared with the data after subsequent carburization, show that a sub-surface region was supplied with carbon, during the latter part of the heating, from both the core and the carburizing gas. This region is marked by the low spots in the final curves in Fig. 3 and 4. Irrespective of whether the maximum carbon at the surface (1.35+ for 1700° and 1.24+ for 1600° F.) is *higher* than equilibrium, it should be evident that the low spots in the final curves cannot be higher than A_{cm} for the respective temperatures. The 1.43% carbon core does not supply carbon readily to the decarburized zone *above* the point where carbon is in solution for the temperature employed — that is, it cannot supersaturate austenite. There is no sharp break in the carbon-depth line, as might be expected, but the gradient for 1600° F. remains very steep. Although exact equilibrium conditions may not have been attained

Fig. 4 — Carbon-Depth Curves of High Carbon Steel After Decarburization and Subsequent Carburization at 1600° F.



in this limited time, note that the saturated solution at 1700° F. has about 1.30% C, while 1.15% C is indicated for 1600° F. (1.32 and 1.18 are the respective figures scaled from Fig. 2.)

We also took $\frac{1}{16}$-in. plates of Armco iron, 2 in. square, and carburized one for 16 hr. at 1700° F., and another 40 hr. at 1600° F. — thus attempting to carburize them through and through, much like the old cementation process for making "shear steel". Gas used was the

mixture of natural gas and drycolene mentioned earlier in this article. That the time was sufficient was indicated by companion plates, withdrawn at shorter intervals. For example, analyses of through drillings of plates carburized at 1700° F. were as follows:

Time	Carbon
¾ hr.	0.42%
4	0.97
9	1.32
16	1.34

One of the plates, fully carburized, was then cut in half and one half ground 0.008 in. on each face to remove high carbon surface, if any. Samples were then taken from both pieces — one surface ground, and the other the full plate as carburized. Samples for chemical analysis were not surface cuts, but were drillings through the entire plate thickness. Results follow:

Temperature	Unground Half	Ground Half
1600° F.	1.16% C	1.16% C
1700	1.34	1.33

We could therefore find no increase in carbon in the full plate over the plate with the surfaces removed, which indicates that any high carbon as a surface condition must have been of *very* shallow depth. The values of 1.34% C for 1700° F. and 1.16% C for 1600° F. agree well with the values for plain carbon steel found in the "Case Depth" article and shown in Fig. 2.

Abnormally High Carbon Surfaces

This is not to argue that high surface carbon contents are impossible. They can be demonstrated by carburizing shim stock, 0.002 in. thick. That this higher surface carbon has little influence in the ordinary carburizing operation is fairly well shown by the check on the $\frac{1}{16}$-in. plates. I cannot agree that the variation of carbon content at the surface with temperature is explainable on the basis that absorption rate is higher than the diffusion rate. Boegehold and Tobin state this hypothesis (which I challenge) in their contribution to the Carburizing Symposium:

> "The [inverse] variation of carbon content at the surface with temperature is explainable on the basis of absorption rate versus diffusion rate. At the lower temperatures, the absorption rate is so much faster than the diffusion rate that a supersaturated layer of austenite is produced. The diffusion rate increases with increasing temperature causing the surface carbon to decrease steadily until finally a point is reached at very high temperatures where the diffusion rate is fast enough to prevent the formation of a saturated austenite at the surface."

When very high carbon concentrations of the "cast iron" order are found for any appreciable depth, I believe you are justified in investigating the atmospheres which surround the carburized surface, as well as the steel composition. When gas mixtures far from equilibrium are introduced into the carburizing chamber (for example air and hydrocarbons) many reactions are possible, such as the deposit of hard coke on the steel surface, the etching and corrosion of the alloy container, and so on. This condition is not uncommon, both with solid carburizers (when boxes are partially filled with carburizer, or have loose fitting covers) and in gas carburizing (when given an insufficient gas flow or an incorrect mixture). When oxides or nitrides may be intermittently formed on the steel surface, the case characteristics may also be influenced to the depth that these oxides or nitrides may diffuse. Undoubtedly any OH radical present will, under certain conditions, accelerate a "chain-making" reaction that will influence the steel surface.

Abnormal boundary conditions such as listed above should be closely checked in connection with the extreme surface conditions which are often reported as carbide layers. It must be pointed out that retort pressure, gas mixtures, and other conditions were carefully regulated in the tests which we reported, in an effort to maintain constant and normal boundary conditions. This is extremely important if concise evaluations are to be made.

Carl Shapiro and Jerome Strauss gave a paper at the A.I.M.E. meeting in Chicago last fall, entitled "The Influence of Various Elements upon the Position of the Eutectoid in the Iron-Carbon (Carbide) System", and printed as Technical Publication No. 1646 in *Metals Technology* for December 1943. This article should throw some light on surface carbide formations, which in alloy steels are no longer the "simple" Fe_3C but may be quite complex compounds or crystals of iron, alloying elements and carbon. From a straight diffusion standpoint, however, it is difficult to postulate any movement of carbon from the steel surface, to build up a concentration above that percentage of carbon which is soluble in austenite at the given temperature.

Carburizing still is a controversial subject, and will remain so until all factors are placed in their proper relationship. In this connection the work of Metals Research Laboratory at Carnegie Institute of Technology seems to be the proper line of attack.

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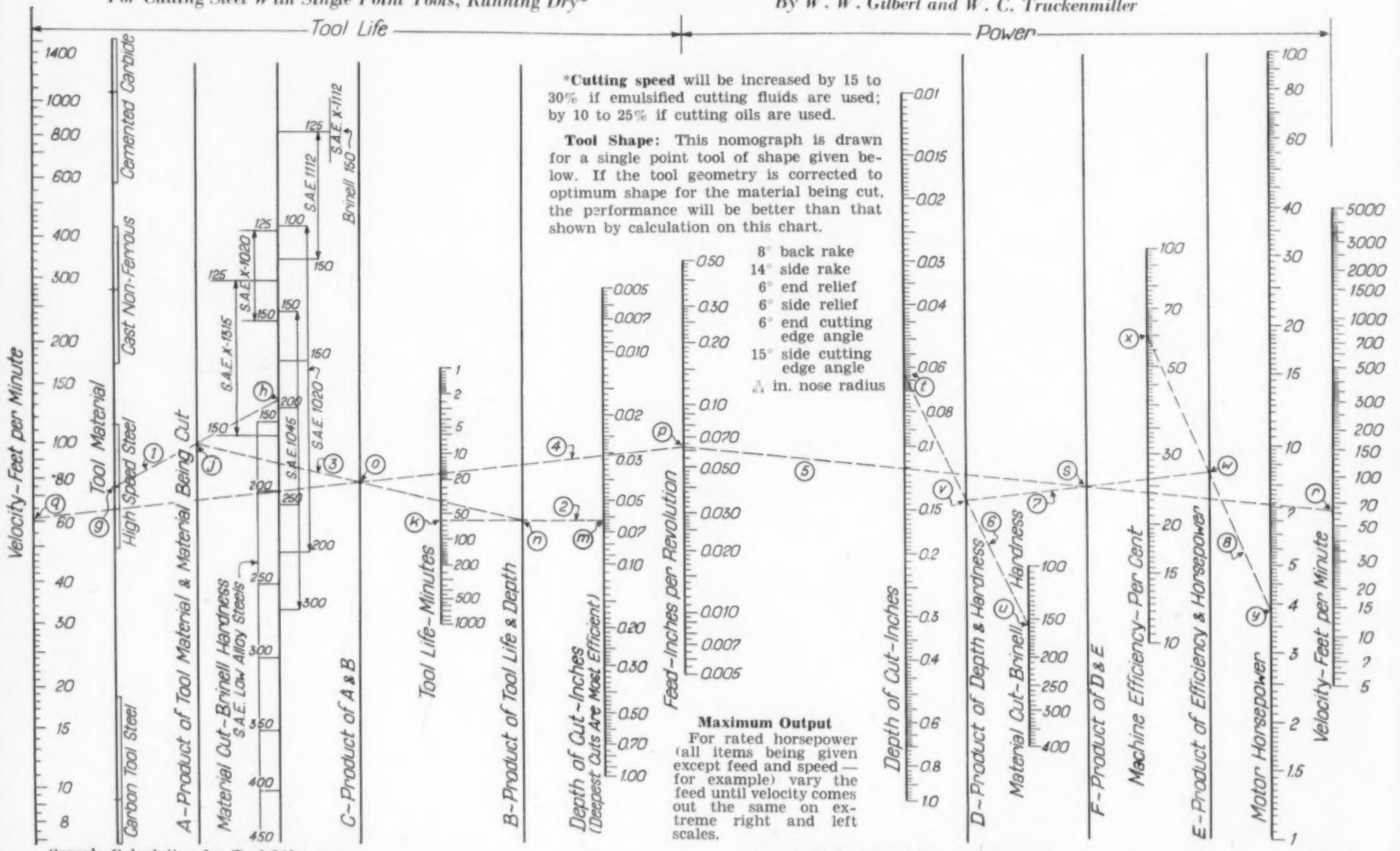
Metal Cutting Nomograph

Courtesy, American Society of Mechanical Engineers

*For Cutting Steel With Single Point Tools, Running Dry**

By W. W. Gilbert and W. C. Truckenmiller



***Cutting speed** will be increased by 15 to 30% if emulsified cutting fluids are used; by 10 to 25% if cutting oils are used.

Tool Shape: This nomograph is drawn for a single point tool of shape given below. If the tool geometry is corrected to optimum shape for the material being cut, the performance will be better than that shown by calculation on this chart.

- 8° back rake
- 14° side rake
- 6° end relief
- 6° side relief
- 6° end cutting edge angle
- 15° side cutting edge angle
- 1/64 in. nose radius

Maximum Output

For rated horsepower (all items being given except feed and speed — for example) vary the feed until velocity comes out the same on extreme right and left scales.

Sample Calculation for Tool Life:

Given—Tool material: high speed (Point **g**) } Draw Line 1,
Material cut: S.A.E. 1020, 160 hard (Point **h**) } Establish Point **j**
Desired tool life: 60 min. (Point **k**) } Draw Line 2,
Depth of cut: 0.0625 in. (Point **m**) } Establish Point **n**
Draw Line 3, between **j** and **n**, establishing Point **o**
Feed: 0.0625 in. per revolution (Point **p**)

Sample Calculation for Power Required:

Given—Feed: 0.0625 in. per revolution (Point **p**) } Draw Line 5
Velocity: 60.5 ft. per min. (Point **r**) } Establish Point **s**
Depth of cut: 0.0625 in. (Point **t**) } Draw Line 6
Hardness of steel: 160 Brinell (Point **u**) } Establish Point **v**
Draw Line 7 between Points **v** and **s**, establishing Point **w**
Machine efficiency: 60% (Point **x**)

Metal Progress, April 1944, Page 686-B

Letters From Home and Abroad

Weld Tests— Small Samples Versus Full Scale

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

Two recent articles on weld quality by highly competent observers leave us with a slightly undressed and embarrassed feeling. These two articles appeared in engineering magazines published on opposite sides of the Atlantic, but this certainly has no scientific significance.

One is by Messrs. Gayley and Willis of the Philadelphia Navy Yard. It appeared in *The Welding Journal's Research Supplement* in January 1944, and showed how remarkable mechanical properties can be produced by the rapid weave technique, where the heat input and other welding conditions are adjusted so the molten pool is about ten times the diameter of the electrode, and the welder lays down a thin layer as fast as he can insure good penetration. The authors emphasize that the multiple heatings so given to the deposited metal completely refine the original cast structure (columnar and coarsely dendritic) and the weld has the fine, uniform microstructure of the best wrought steel. Average tensile properties are 70,000 psi. ultimate, 55,000 psi. yield, 25% elongation in 2 in. and 45% reduction of area. Tensile impact on a 0.36 by 0.5-in. specimen shows 140 ft-lb. energy absorption, 40% elongation in 0.5 in., and 60% reduction of area. Truly remarkable properties!

The other article by H. B. Ferguson, director of G. A. Harvey & Co. (appearing in *The Engineer*, London, of Dec. 17, 1943) argues that other things besides fine-grained weld metal are necessary to make an exemplary weldment. In fact, he states his experience that the joint, as a whole (as measured by bend test, softness of the heat-affected zone in the plate adjacent to the weld, and the fatigue endurance) "is improved when large electrodes with heavy current inputs and slow rates of welding speed are adopted". He readily admits that weld metal in such joints will be highly dendritic and have Izod impacts of no more than 30 to 40 ft-lb. but his attitude is evidently that he would rather have a satisfactory weldment than a fine microstructure or a high Izod test.

Of course there are a great many things about welded joints that we do not know yet. For that matter, we are beginning to suspect that we have overlooked a good deal in the physical properties of the metal we use. Mr. Ferguson's article is worthy of study, as it exposes rather thoroughly our lack of knowledge about why welds behave the way they do. It seems he has left the metallurgists a little on the naked side in so doing. But he has at least pointed the way to knowledge — the full scale tests. And there is sound engineering backing for that idea on this side of the Atlantic.

We have all been pretty well scared to put too much reliance on conventional impact tests, and Mr. Ferguson's recommendation of full scale tests both for impact and fatigue properties seems to be very sound indeed. On one series of full scale fatigue tests undertaken by the present writer, where we expected failure to occur alongside the weld due to the hardened zone (it was plate with 0.20% to 0.30% carbon), none of the specimens broke there.

High bend ductility is possible in weld metal even though dendritic. Perhaps the fact that this metal is pretty well souped up with manganese and silicon, along with various alloying elements, may explain something. It certainly does explain that there is enough air trapped in the dry flux to make it necessary to add deoxidizing elements.

The story is told of the Navy testing a marine engine by every block test anyone could suggest. After the engine stood all of that successfully, the engine was put in a ship; the crew then ran the ship 6000 miles down deep into the south Atlantic and back without ever stopping the

engine. That is the kind of a test that tells a story for certain. All other things we do are in the line of finding out physical behavior by some short cut in the laboratory.

On the other hand, we had a case not so long ago of a manufacturer who put out a slightly changed design without full scale service test. While the weld was metallurgically reprehensible it apparently was good enough for the purpose — at any rate, it was good enough to pass the perfunctory tests given at the plant. But field failures soon began to come in. Investigation showed that the trouble was that one member of the structure was too flexible. The weld occurred at the first point of restriction to movement. By merely stiffening the defective member, the weld trouble disappeared. That one could have been caught before it got out, but it just wasn't.

The ground is beginning to tremble under our feet due to need for using physical properties of metal up to a yield point which is close to the ultimate strength. Henry Ford did not do our mental aplomb any good when he began making crankshafts out of something he calls cast iron, that does not have an appreciable impact strength as measured by conventional methods!

ROBERT E. KINKEAD
Consulting Engineer, Welding

Ghostly Bomber

COLUMBUS, OHIO

To the Readers of METAL PROGRESS:

We recently examined a failed aluminum alloy sand casting which turned out to be quite porous. During the preparation of the specimen, the metallographist examined it while it was only partially polished, and noticed a very peculiar condition, never before observed. It appears to be approximately a three-quarter front view of a stick of bombs dropped from an airplane. To complete the illusion, a phantom airplane was placed over the negative when it was printed. The magnification is approximately 75 diameters.

We can offer no explanation for this condition inasmuch as subsequent polishing removed the "bombs" entirely. Also if anyone were to get very technical about the whole picture, I am afraid we would have difficulty in explaining why the "bombs" are at such an angle. The thought occurs that they were dropped one at a time from an extremely high speed airplane which should be well out of the picture! Also the type of terrain which the airplane is flying over would be somewhat difficult for a civilian to explain.

L. P. WOOD
Materials Engineer
Curtiss-Wright Corp., Airplane Division

Inclusions in Titanium Steels

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

Metallurgists have been familiar for many years with the fact that iron or steel in which small amounts of titanium were present — either as a deliberate addition during steel making, or as a result of the use of titanium-bearing ores — contained, as a special constituent in the microstructure, small, angular non-metallic inclusions, which might be colored yellow, orange (or salmon pink), brown or gray.

It seems probable that these inclusions, which have been variously described by different investigators as nitride, cyanide or cyano-nitride of titanium, were observed in the earliest days of metallography because, some years ago, the writer had the privilege of examining a number of Dr. Sorby's original microsections and in one of these — a sample of cast iron — these typical titanium inclusions figured prominently; it is unlikely that their presence could have been overlooked by that meticulously careful observer.

Until recently, accurate information as to the composition of these inclusions appears to have been lacking. For remedying this, metallographers owe thanks to Dr. Hume-Rothery and his collaborators at Oxford University. In a recent paper before the Iron & Steel Institute ("On the Carbide and Nitride Particles in Titanium Steels") they present microscopic, X-ray and analytical work on a series of commercially pure steels containing up to 6% titanium and from 0.10 to 1.0% carbon. The evidence indicates that these inclusions consist of solid solutions of

titanium nitride and carbide of the $Ti(C_xN_{1-x})$ type, and their actual composition may vary appreciably. No evidence was obtained of any tendency to form the cyanide $Ti(CN_2)$ or the cyano-nitride.

Dr. Hume-Rothery and his colleagues also observed that the general effect of increasing carbon content in the steel was to change the color of the inclusions in the direction yellow, orange, brown, gray — the gray particles being almost indistinguishable from those of the titanium carbide. At the same time, they point out that duplex particles (having yellow or orange centers with brown or gray rims) frequently occurred, and also that particles of different color were observed in each steel.

X-ray tests on residues separated electrolytically from steel containing 2.28% titanium and 0.05% carbon, in which the angular particles were nearly all of a yellow color, showed that these particles had a lattice spacing slightly but definitely greater than that of a sample of titanium nitride prepared synthetically, namely 4.240 to 4.241 Å as against 4.233 Å. Moreover, the lines in the X-ray diffraction pattern were fuzzy, indicating that even in this low carbon steel the particles were not all of the same composition, but contained different amounts of carbide.

More complete data were obtained from steel containing 5.8% titanium and 0.58% carbon. X-ray patterns obtained from residues separated from this steel showed a set of sharp lines corresponding to titanium carbide and having a lattice spacing of 4.325 Å, and also a set of diffuse lines similar to those in the first sample but corresponding to a much wider range of lattice spacing. The whole of this latter range, however, was greater than that of the synthetic titanium nitride.

The residue was also examined chemically, advantage being taken of the fact that pure titanium carbide is unattacked by chlorine at 575° F., whereas the yellow, orange and brown particles — consisting of solid solutions of the carbide and nitride in varying proportions — are attacked, producing free carbon, nitrogen, and titanium tetrachloride which is volatile at 575° F.

The results obtained showed that on the average, the colored particles in this relatively high carbon steel contained about 25% titanium carbide in solution in the nitride. It was obvious from the X-ray diffraction pattern that the actual amount varied appreciably in different particles.

The results indicate, therefore, that even in a very low carbon steel, the particles are not pure nitride but contain some carbide, probably only a small amount. In higher carbon steels the proportion of carbide in the particles increases, though the nitride still predominates; moreover in any given steel the actual proportion of carbide to nitride may differ appreciably between individual particles.

J. H. G. MONYPENNY
Metallurgist
Brown, Bayley's Steel Works, Ltd.

Rapid Nickel Determination

HOUSTON, TEXAS

To the Readers of METAL PROGRESS:

We are sending a rapid colorimetric determination of nickel in steel, used in our laboratory for several months and found quite reliable. [It is printed in the column just below, and so arranged that it can be placed in a standard loose leaf notebook.] It requires such a small

Colorimetric Determination of Nickel in Steel

By H. L. Mauzy and H. Yellin

Procedure — A 0.100-g. sample is weighed into a covered 150-ml. beaker and dissolved in 10 ml. of dilute hydrochloric acid (1:1). Add 10 ml. of dilute nitric acid (sp.gr. 1.16) to oxidize carbides and boil down to a volume of approximately 5 ml. Cool somewhat and wash down the cover glass and sides of the beaker with distilled water. Transfer to a 100-ml. graduate or volumetric flask, washing the beaker with distilled water several times and finally making up to the mark with distilled water. Mix well and accurately measure (with a pipette or graduate) 25 ml. into another beaker. Add the following reagents in the order given, stirring after each addition: 25 ml. of distilled water, 10 ml. of 10% citric acid, 5 ml. of saturated bromine water, 10 ml. of dilute ammonium hydroxide (1:1) and 3 ml. of 1% dimethylglyoxime. Transfer to a 100-ml. graduate or volumetric flask and make up to the mark with distilled water. Mix well and pour 23 to 25 ml. in a clean cell of the Fisher electrophotometer, or other similar equipment. Take a reading immediately on the "A" scale using the green filter No. 525-B. Determine the percentage of nickel from a calibration curve.

Observations — By the procedure outlined above, nickel contents up to 0.80% may be checked with an accuracy of ± 0.01% in 10 to 15 min. This covers the range of residual nickel in steel, and all the present National Emergency steels. For nickel contents ranging up to the S.A.E. specifications (2000, 3100, 3200, 4600, and 4800 series) smaller aliquot portions of the original 100-ml. sample must be taken — for example, 5 ml. for a 4800 series sample. This procedure, of course, decreases the accuracy in direct ratio to the multi-

amount of time — 10 to 15 min. — that it enables us to determine residual nickels on all shipments of steel going into heat treated parts, and we can do so without overloading our existing facilities. With the advent of the National Emergency steels and with the increasing use of nickel-bearing scrap in the manufacture of all steels (including "straight carbon"), an accurate and rapid method for determining these low alloy and residual nickels should be of considerable value to others.

The gravimetric determination with dimethylglyoxime (while unquestionably accurate for all ranges of nickel content, from residual values up through the various alloying percentages) has the disadvantages of all gravimetric determinations, namely, the time-consuming operations of precipitation, filtration, and drying or igniting to constant weight. The volumetric cyanide-silver nitrate method requires rather expert manipulation for accurate reproducible results as well as two or more strengths of reagents to cover the nickel ranges now being encountered.

Our colorimetric method overcomes most of these objections since it is rapid and reproducible, requires only a small amount of sample, and no standardized reagents. This method is based on the observation that dimethylglyoxime reacts with nickel in alkaline solution to give, in the presence of a strong oxidizing agent, a wine-red colored solution that obeys the Lambert-Beer law. The intensity of this color may be determined by any of the colorimetric devices now on the market and these results converted into percentages of nickel. No interference has been observed from the various elements encountered so far in commercial steels.

H. L. Mauzy
H. Yellin
Chief Chemist and Junior Chemist
Reed Roller Bit Co., Transmission Division

plication factor involved (5 for the 4800 series, so that the accuracy is ± 0.05%), but even so, the procedure provides a quick method for classifying an unknown steel into its proper specification range.

Reagents Required

1. Dilute hydrochloric acid (1:1): Add 250 ml. of HCl (sp.gr. 1.18) c.p. to 250 ml. of distilled water.

2. Dilute nitric acid (sp.gr. 1.16): Add 150 ml. of HNO_3 (sp.gr. 1.42) c.p. to 400 ml. of distilled water.

3. Citric acid 10%: Dissolve 50 g. of citric acid, U.S.P. or better, in distilled water and make up to 500 ml. with distilled water.

4. Saturated bromine water: **(Caution:** Use in hood.) Add an excess of c.p. bromine to 1 liter of distilled water. Store in dark and use the saturated solution by decanting into another bottle as needed.

5. Dilute ammonium hydroxide (1:1): Add 250 ml. of NH_4OH (sp.gr. 0.90) c.p. to 250 ml. of distilled water.

6. Dimethylglyoxime 1%: Dissolve 5 g. of dimethylglyoxime in 500 ml. of synthetic methanol.

Calibration Curve — Follow the above procedure with two or more steels of known nickel content (below 0.80% and preferably with considerable difference in nickel) and plot the percentage nickel versus the scale "A" reading. The resulting graph should be a straight line, since the color intensity follows the Lambert-Beer law.

In the absence of steels of known nickel content a curve may be made by adding varying volumes of a standard nickel solution to 0.100-g. samples of nickel-free iron dissolved in dilute hydrochloric acid and oxidized with dilute nitric acid. The regular procedure is then followed, the amount of nickel solution added being converted to a percentage basis.

Powder Metals
An Outline for Scientific Studies

New York City

To the Readers of Metal Progress:

During the A.I.M.E. symposium on powder metallurgy held in New York in February, one of the speakers stated that, according to some metallurgists of high rank, powder metallurgy has no *raison d'etre*, as it cannot do anything that cannot be done by such orthodox means as casting, forging, screw machining, die casting, or stamping.

This general statement cannot possibly be accepted as correct. Whoever the scientists may be, they probably did not realize, when making such a statement, that there are many metal powder products that cannot be produced by any other means. It need only be mentioned that the commercial manufacture of tungsten (or for that matter any of the high melting point metals), of tungsten carbides, of porous material, and of mixtures of metals with non-metals is only possible because of powder metallurgy.

Further, a statement was made that powder metallurgy is not a science but an art. Everyone associated with the development of powder metallurgy is aware of this fact, but steps have been and are being taken to bring the science abreast of the art.

In furthering the science, it is essential that we look to the starting point, namely the produc-

tion of metal powders. It will be observed that almost every scientific paper presented during the past twelve months dealt with some feature of the *finished product*. It seems to have been overlooked that to make a finished product of optimum and closely controlled characteristics it is essential to produce powders that allow a reasonable expectation of obtaining such properties in the finished product. At the present moment, there are only poorly defined standards for the chemical and physical characteristics of powders.

A powder may have the desirable chemical and physical properties, but more than these requisites are necessary for achieving certain specific results. For instance, powders react differently in different atmospheres. Varied pressure exerted per square inch produces varying results in the finished part. These factors are only a few that must be seriously studied if powder metallurgy is to develop into a science.

It is for this reason that the following points are enumerated as a basis for study. Those who have the development of the science of powder metallurgy at heart will no doubt consider this suggested study as a starting point, add to it, and by reporting their results will obtain for powder metallurgy its fully deserved recognition as a science.

Before tabulating the various points that should be helpful in setting up such a study, two facts should be stressed:

1. Different powders (powders of the same metal produced by different methods) react differently under the same processing.

2. Similar powders react differently under different processing all the way along the line, even after the compact has been formed.

The following tabulation covers the essential points to be considered:

1. Method of production:
   - *(a)* Electrolysis.
   - *(b)* Gas reduction.
   - *(c)* Metal hydride reduction (considered separately, although this is also a gas reduction).
   - *(d)* Atomization.
   - *(e)* Carbonyl process.
   - *(f)* Other methods, mechanical, such as grinding or filing.
2. Grain size of the powders.
3. Grain structure (globular, angular, stringy, acidular, or other).
4. Grain assortment in a given mass.
5. Mixing of powders and time required. (Depending on what is desired, a homogeneous mixture can be produced or a coating of a softer powder over a harder powder, such as cobalt over tungsten.)
6. Behavior of powders:
   - *(a)* With all or a large proportion of fines. (Powders of micron-sized particles are now available and in demand.)
   - *(b)* With different grain assortments. (In both *a* and *b*, (1) under different pressures; (2) under different atmospheres.)
7. Standards of determining:
   - *(a)* Green strength.
   - *(b)* Loss in weight.
   - *(c)* Shrinkage.
   - *(d)* Expansion.
8. Standards for test bars to determine:
   - *(a)* Tensile strength.
   - *(b)* Elongation.
   - *(c)* Impact strength.
   - *(d)* Shear strength.
   - *(e)* Fatigue.
   - *(f)* Behavior under cold forging.
   - *(g)* Behavior under hot forging.
   - *(h)* Behavior under bend test.
   - *(i)* Hardness. (Unless parts are absolutely dense, ordinary hardness testing methods are not adaptable.)
9. Standard tests for machining, corrosion and plating. (These will become increasingly important with the growing use of iron and iron alloy parts made from powders.)
10. Behavior of powder:
    - *(a)* Under vacuum pressing.
    - *(b)* When pressing evacuated powders.
    - *(c)* Under hot pressing.
11. Behavior of powder:
    - *(a)* In mechanical press.
    - *(b)* In hydraulic press.
    - *(c)* In other presses.
    - *(d)* In a resistance furnace.
    - *(e)* In an induction furnace.
    - *(f)* In an oil furnace.
    - *(g)* In a gas furnace.
    - *(h)* In other furnaces.
12. Sintering time and time to reach sintering temperature differ with different powders.
13. Influence of water vapor in sintering atmosphere (particularly important when sintering brass and ferrous material, or when annealing powders before compression).
14. Amount of gas dissolved or adsorbed during sintering.

CHARLES HARDY
President, Hardy Metallurgical Co.

An interplay of ideas derived from the theoretical progress of leisurely solidification of solid solution alloys, and the actualities of the situation as determined in melting shop and casting aisle, clarifies the puzzling occurrences of less-than-normal segregation — even negative segregation

Segregation in Alloy Ingots and Large Castings

A MOST NOTEWORTHY feature of the A.I.M.E.'s symposium on segregation, other than the large interest manifest, was the inclusion of both steel and non-ferrous ingots,— again in conformity with the trend toward generalization in metallurgical thinking, commented upon frequently. (Unfortunately the present reporter's limitations as to time and competence make it necessary to confine this account principally to steel.)

It was fitting that the entire subject should by opened by a discussion of the fundamental principles underlying the segregation of alloy castings, ably conducted by R. M. Brick of Yale University's faculty. He pointed out the essential difference between micro-segregation, caused by solidification of a solid solution alloy system and which is illustrated by a metastable condition of solidification causing "coring", and macro-segregation which is characterized by a composition gradient between the center of a cast section and the surface layers. Macro-segregation, especially of rimming steel ingots, is of more immediate industrial concern; micro-segregation can frequently be corrected by commercial annealings.

Normal and inverse segregation, especially the latter, was a subject provoking much discussion. Some interesting theories, particularly concerning inverse segregation, were offered. Professor Brick defined both types of segregation, stating that if the compositional difference is of the same type as "coring", the first parts to freeze being enriched in higher melting constituents, the effect is called normal segregation. When that portion of the casting which apparently solidified first shows a higher concentration of low melting constituents than the average analysis would imply, the effect is called inverse segregation.

If solidification takes place by the growth of dense, impermeable crystals (with no residual liquid layers or interdendritic channels), in accordance with temperature gradients existing in a liquid alloy cast in a cold mold, and if little diffusion occurred, all segregation would be of the normal type; likewise a much larger difference in composition would exist from surface to center than is ever actually found. This indeed would be an unfortunate situation. Fortunately for the metallurgist the dendritic form of crystallization seems to be universal, as well as the presence of interdendritic channels. Physical forces set up in solidification, such as internal gas pressure and contraction effects, can influence the movement of the remaining liquid of low melting point through these channels.

General Considerations

In summary, Prof. Brick listed the main factors concerned with segregation as:

1. Fairly rapid solidification of an alloy over a range of temperature leads to metastable conditions of coring within solid solution dendrites and an associated abnormal enrichment in low

Reported by S. W. Poole
Supervisor of Metallurgical Research
Republic Steel Corp.
Central Alloy District, Massillon, Ohio

melting point constituents of the final liquid to freeze.

2. The dendritic form of solidification leaves interdendritic channels which, filled with the low melting point constituents, reduce the tremendous differences in composition found in "cored" structures to relatively small differences on a macro-segregation scale.

3. The formation of internal gas bubbles creates a positive pressure, forcing liquid of low melting point to the surface areas. This effect is a potent cause of inverse segregation.

4. A more fundamental aspect of segregation involves contraction and associated low pressure areas in interdendritic channels. The implications of this situation are modified by the possibility of segregation in the *liquid* phase — an enrichment in lower melting point constituents at the solid-liquid interface.

5. Gravity segregation, dependent on difference in density between liquid and solid phases or two liquid phases.

In discussion, Earle C. Smith of Republic Steel Corp. pointed out that, contrary to expectation, extremely slow cooling of solid solution alloys may produce extreme segregation instead of a homogeneous alloy. As an example he cited the segregated iron-nickel phases in meteoric iron which, in view of the conventional iron-nickel solid solution alloy diagram, cannot be adequately explained. A. J. Smith of the Lunkenheimer Co. said he had been considerably helped in explaining segregation by considering dissolved gas as an "alloy" constituent.

Examples of all of the kinds of segregation, mentioned by Brick, have been observed among the many aluminum alloy compositions in current production by Louis W. Kempf of Aluminum Research Laboratories in Cleveland. He added that normal segregation is generally to be associated with slow freezing while a fast freezing rate favors inverse segregation. He also described what appears to be a new form of normal segregation in which the composition changes occur in a repeating pattern along the axis of freezing. Mr. Kempf has a right to speak feelingly of this matter, for few outside the aluminum pioneers realize the "stopper" to American production of strong aluminum alloys that existed in our early inability to cast a bar or slab ingot that was not found to be ruinously segregated.

Large Steel Ingots and Castings

In summarizing some of the underlying factors involved in segregation in steel ingots and large castings, B. M. Larsen of the U. S. Steel Corp. Research Laboratory selected the following as significant:

1. Considerable heat is evolved in the freezing of steel (100 Btu. per lb.), the outflow of which determines the rate and sometimes the direction of crystal growth.

2. Skeletal types of crystals, such as dendrites, tend to grow faster along the original axis of growth than in other directions.

3. Crystal nuclei have higher iron content, thus leaving an adjacent layer higher in impurities and lower in freezing point and thus establishing a concentration gradient.

4. As a result of these concentration gradients, a rate of diffusion or mixing is introduced which limits the rate of freezing, thus favoring dendritic crystal growth. However, this dendritic crystal growth can be suppressed by vigorous stirring, natural or artificial, vigorous enough to eliminate the effective concentration gradients.

5. There is an appreciable difference in specific gravity between liquid metal and solid crystallites; this is not large in terms of percentage (about 7%) but the absolute difference is equal to about half the specific gravity of water, thus permitting rather rapid settling of unattached crystallites. This effect is of considerable importance in forming the "sedimentary cone" in the lower central third of killed steel ingots. If the ingot is of alloy composition these unattached crystallites are lower in solute alloy elements than the residual liquid and this explains the impoverishment in alloy elements that is frequently found in this position of the ingot.

6. In the solidification of rimming ingots the evolution of gas by the carbon-oxygen reaction in liquid iron is a factor of considerable importance. Bubble formation is favored by a somewhat rough solid surface and, on the other hand, can be repressed by ferrostatic pressure. Variable oxygen content of the steel can cause a wide variation in reaction tendency; this has important consequences with respect to stirring the molten metal and forming blowholes.

Some interesting data concerning segregation ratios in steel ingots were presented by Mr.

Segregation Ratios in Steel Ingots

Weight	C	Mn	Si	P	S	Ni	Cr	Remarks
110 tons	3.07	1.25	1.17	2.52	3.48	—	—	Killed steel
10¼	1.73	1.16	1.15	1.33	3.87	—	—	Killed steel
¾	1.18	—	—	1.57	1.50	1.04	—	Killed steel
3	2.04	1.09	—	2.40	2.05	—	—	Rimming steel
3	2.72	1.07	—	3.20	5.43	—	—	Rimming steel
7¾	2.27	1.11	—	2.62	3.22	—	—	Semi-killed plate steel

Larsen. Some examples cited were concerned with killed and rimming steel ingots cast in chill mold, in which the segregation ratios (highest chemical analytical divided by the lowest analysis) were on the order given in the table at the top of the column.

Among the segregation ratios of 30 ingots cited by Mr. Larsen the ratios for manganese never exceeded 1.27; nickel and chromium for several alloy ingots examined showed maximum ratios of 1.11 for nickel and 1.20 for chromium; the highest silicon segregation ratio (for a 172-ton killed ingot) was only 1.43. Carbon, sulphur and phosphorus, as expected, showed the most variable and the highest segregation ratios.

17-Ton Alloy Ingot

An interesting study of a 34,000-lb. killed alloy steel ingot was described by S. W. Poole and J. A. Rosa of Republic Steel Corp. This large ingot (it was 15 ft. 4 in. high, 34 in. square on the shoulder below the hot top, and 27 in. square at the butt end) was sectioned longitudinally near the center with a special oxy-acetylene cutting torch. A longitudinal section 4 in. thick was then removed from the ingot in the same manner, subsequently annealed and then machined on a large planer to the exact longitudinal center plane. This surface was sulphur printed on a single large sheet of sensitized printing paper, 40 in. wide — the print, incidentally, is on exhibit in the Metallurgical Laboratory, at the Canton Steel Division of the Republic Steel Corp. It shows rather well the dendritic zone, primary threadlike sulphur segregates, and the somewhat porous, "herringbone" area along the central axis.

Actual ladle analysis, as well as average analyses of outer zone and entire body of this electric furnace, alloy steel ingot was as shown in the table opposite. Study of the voluminous data accumulated showed that segregation was minor in its occurrence within the body of the ingot. What segregation was present was confined to the lower third, and was of the inverse type, this region being impoverished in alloying elements. However, in view of the mass of the ingot, the distribution of elements was remarkably uniform.

Earle Smith, in commenting on the results of this work, called attention to the commercial aspects of the segregation problem. Wide chemical limits in specifications ease the producer's problems in making heat after heat within the limits, as measured by ladle analysis. Segregation makes it likely that a single bar from such an acceptable heat may give returns that fall outside the limits. Even if within chemical limits, the variation may be enough to cause unacceptable variations in heat treatment schedules and in machinability. Hence the natural tendency for consumers to work toward tighter and tighter chemical limits. Another interesting trend was discussed at length at one of the round table meetings at the ⊜ convention last October, namely toward considering performance of the steel in a given application as a basis for specification rather than a closely restricted quantitative chemical analysis. As it stands now, Mr. Smith estimates that about only about half the steel products are ordered on chemical specifications. This may be rather higher than a peacetime ratio, owing to the large amount of steel produced for its ballistic properties, and for the Navy, which generally is more interested in performance than in chemistry.

He also thought that not enough consideration was given to segregation in the metal bath in steel melting practice. He cited as an example the difficulties encountered with segregation in the ladle when making the old type NE9440 analysis, containing 0.60% silicon. Another aspect of segregation in which oxygen is the chief offender is segregation of oxygen as FeO in ingot iron, very important and pertinent as regards the quality of this material.

Representative Analyses From 17-Ton Ingot

Element	Ladle Analysis	Ingot Body (Average)	Outer Zone (Average)
Carbon	0.380	0.374	0.379
Manganese	0.65	0.66	0.66
Phosphorus	0.012	0.010	0.010
Sulphur	0.014	0.015	0.015
Silicon	0.30	0.31	0.31
Nickel	1.86	1.86	1.86
Chromium	0.81	0.83	0.83
Molybdenum	0.34	0.35	0.35
Vanadium	0.07	0.07	0.07

Rimmed Steel

The relationship between openhearth practice and segregation in rimmed steel was discussed in an interesting manner by J. W. Halley and G. L. Plimpton of Inland Steel Co. This matter is considerably more complex than in the killed or semi-killed ingot because of two distinct stages in the solidification of rimmed steel. In the earlier stage, chemical reactions cause an evolution of gas and vigorous stirring, which in turn is responsible for a degree of negative segregation unique to rimmed steel. After gas evolution has ceased, segregation follows the general pattern of a more completely deoxidized steel.

From the standpoint of segregation, the steel producer's aim in rimmed steel of high quality is to effect a maximum negative segregation in the rim zone without excessive concentration of undesirable elements at the center of an ingot. The composition of the melt, the furnace and pouring practice may be adjusted within certain limits to achieve this. The most important factors noted are:

1. Composition of the steel (with respect to elements which are not subject to elimination from the ingot as reaction products, and which must be held to low values, particularly when their segregation coefficients are high).

2. Vigorous motion of the metal (which removes rejected impurities from the solidifying surface, and may be secured by maintaining a high carbon-oxygen product, a rapid freezing rate and a low pouring temperature).

3. Checking the rimming action (as early as possible by capping the ingot, thus reducing segregation in the core zone).

A factor of considerable interest with respect to segregation phenomena is the distribution coefficient k developed by Hayes and Chipman, and defined as the ratio of the concentration of a given element in the liquid and in solid delta iron. Since the tendency to segregate increases with increasing distance between the liquidus and solidus, the tendency of an element to segregate is given by $1-k$ which is termed the "segregation coefficient".

This concept is of value in dealing with negative segregation in rimmed ingots as it determines the greatest degree of negative segregation theoretically possible. It gives no measure of the extent of positive segregation, except the general one that positive segregation will be greater when negative segregation is greater. An example of the use of this segregation coefficient showing the lowest theoretical composition in the rim by negative segregation for two ladle analyses shows:

Element	Segregation Coefficient	Analysis A		Analysis B	
		Ladle	Rim	Ladle	Rim
Manganese	0.16	0.20%	0.168%	0.40%	0.336%
Copper	0.44	0.08	0.044	0.12	0.067
Phosphorus	0.87	0.020	0.0026	0.080	0.014
Carbon	0.87	0.10	0.013	0.20	0.026
Oxygen	0.90	0.015	0.0015	0.025	0.0025
Sulphur	0.95	0.025	0.0012	0.035	0.0017

However, rimmed steel ingots do not show this degree of negative segregation in practice. During solidification, rimmed steel misses this condition of maximum possible segregation because of the washing action of the liquid metal as it moves upward along the inside surface of the solidified metal. The less pure liquid is not completely removed but a certain portion of it is washed away and mixed with the body of the ingot. The degree to which the theoretical negative segregation will be approached depends upon the efficiency of this washing action, which in turn is controlled primarily by the reaction between carbon and oxygen to form CO and CO_2. The more rapidly this reaction proceeds, the greater the gas evolution and more efficient the washing. The authors found, on 29 x 43-in. ingots weighing 18,000 lb., initial rates of gas evolution were 2½ to 3 cu.ft. per min. decreasing to 1 cu.ft. per min. when capping time approached.

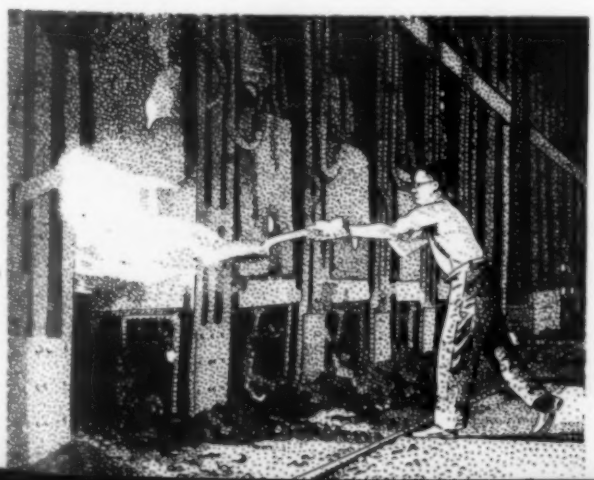
Such features of openhearth practice as affect segregation to a major degree are:

1. Control of carbon, manganese, oxygen and sulphur during melting.

2. Steel temperature; for a maximum freezing rate, the optimum temperature for rimmed steel is just above that at which a skull will form in the ladle.

3. Mold temperature.

4. Mold design, including the factors of height of mold, wall thickness and shape.



Test Plugs Cut From Welds

SOUND WELDS are essential in all important joints, yet there are many times when it is inconvenient, if not impossible, to take certain bulky work to an X-ray machine or to take a portable X-ray machine to the work. The only alternative then available is to take test plugs of the weld to be examined. All welds made within our own yard are under constant supervision and inspection, yet doubtful work must at times be examined. The greatest use of the scheme to be described is on work received from vendors outside the yard. It is necessary to inspect these

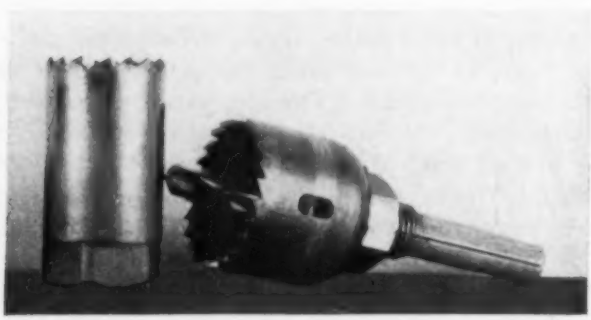


Fig. 1—Photograph of an Arbor Containing Hole-Saw and Pilot Drill, and (Left) the Hole-Saw Itself. It is better to drill a pilot hole, then use a long piece of smooth drill rod where the drill is shown in the above combination

welds to be sure they are sound. Visual defects can of course be spotted. Skilled inspectors and supervisors also recognize tell-tale indications of irregular welding quality, and these give an idea of where the test plugs should be taken.

Two methods are commonly used in taking test plugs: First, by burning a section of the weld out of the seam with an oxy-acetylene flame; the second, by trepanning the test plugs with a "hole-saw".

The method of burning test plugs is not particularly desirable. It creates a heat affected zone of its own which obscures or even obliterates the conditions existing alongside the weld metal. If the plug does have inclusions the action of the cutting torch tends to blow these sections so the final observations are not accurate. Usually there is also a larger repair job to be done in welding up the hole in a sound joint, thus concentrating a greater amount of stress at this point.

The method of trepanning test plugs with a hole-saw involves the cutting (sawing) of a narrow circle of metal out of the weld. Obviously this gives a better visual observation of the plug as a whole, without heat affected zones and without damaging any inclusions or pockets which may be uncovered. Likewise the hole is more easily repaired.

However, we have run into much difficulty and expense in taking test plugs with a hole-saw according to the manufacturer's recommendations, which is to use a hole-saw in the arbor provided, together with a pilot drill inserted therein, all as shown in the photograph alongside. These pilot drills are ¼ in. in diameter; following the manufacturer's recommendations usually five or six drills are destroyed and three to four hole-saws are ruined in the process of taking out a single large plug.

We have found by experience that a better method of taking test plugs consists of first drilling a ¼-in. pilot hole with an ordinary electric or air drill. We then replace the drill in the arbor with a piece of ¼-in. drill rod, projecting

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Fig. 2 — Sound and Unsound Welds Discovered on Contract Work Received From Outside Vendor

far enough to go deep into the pilot hole. The drill rod, having a greater degree of strength and being perfectly smooth around the circumference, guides the hole-saw more evenly and it is thus possible to take any number of test plugs with one drill and one hole-saw. Test plugs are preferably 1¼ or 1½ in. diameter.

After test plugs have been taken, X-rayed, cut in half or otherwise sliced, machined, polished and etched, it is possible to ascertain whether the weld is sound, the joint thoroughly

Fig. 4 — Automatic Welds; Roots Do Not Coincide. Note internal cracks starting at root

fused, the plate properly prepared for welding, and whether the work has been done manually, by automatic welding, or both. The views on this page, adequately described by their captions, show a number

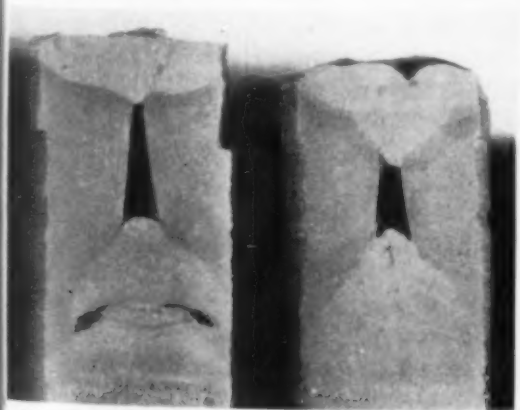


Fig. 6 — Unusually Bad Fit-Up, Glossed Over by Fairly Good Manual Welding

of such plugs. Naturally defectives are in much greater profusion than they are found in our testing laboratory, even when the inspector is guided by external evidence in locating the spots where sub-surface inspection is desirable. It is especially difficult to tell whether fusion in automatic welding is complete, when a back-up strip covers the under side of the seam and is welded into, more or less securely.

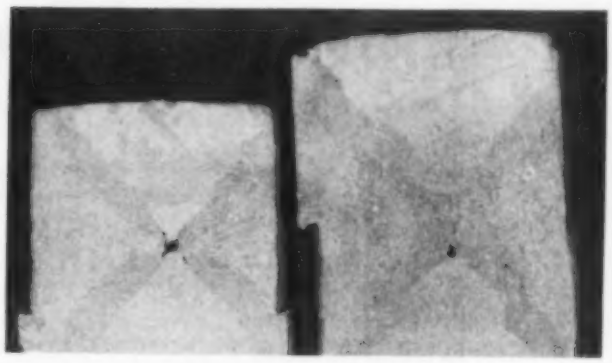


Fig. 3 — Unsound Manual Welding (Incomplete Fusion at the Root) Principally Due to Improper Plate Preparation

Test plugs give concrete evidence that can be examined by all the Inspection Bureaus involved. The amount of repair work is then determined and a complete record made of all the findings.

It is important that a record be kept for future reference and for the Shipping Bureau's use, as it forms a part of the permanent record concerning the history of the ship and the classi-

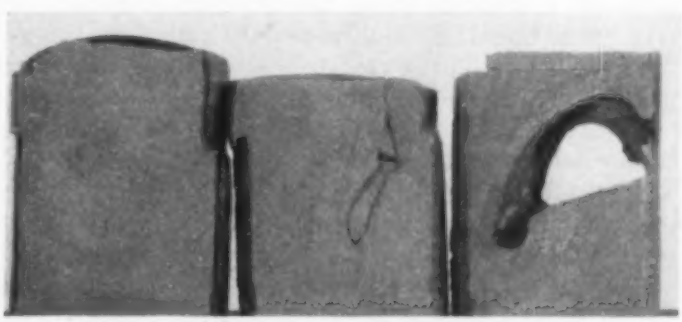


Fig. 5 — One Good and Two Bad Test Plugs From a Section Manual-Welded From One Side and Machine Welded From the Other

fication the hull receives. The records should include the exact location where the plug was taken, the name of the vendor, how the weld was made, suggestions for correcting the condition in the future, a photograph of the plug, information about the repair work ordered, an "OK" on the finished work, and the cost of repairs.

A wealth of metallurgical information was uncovered at the February meeting of the A.I.M.E. In addition to the report below, the reader can turn to the lecture on gray cast iron (page 703) and the discussions on ingot segregation (page 692) and continuous casting (page 497, March issue)

New Studies on Metals, and New Metallurgical Techniques

IT IS NOTABLE that metallurgical research has progressed beyond the place where investigators are primarily interested in accumulating and publishing information about this, that or the other alloy, and are now studying this great body of data in an attempt to find broad relationships. In short, the bricks are available; we are now attempting to build a house which will eventually be called "The Science of Metals".

This trend, observable for some years, was again evident at the February general meeting of the American Institute of Mining and Metallurgical Engineers in New York. For example, James T. MacKenzie in the Howe Memorial Lecture (briefly abstracted on page 710) interpreted the properties of gray cast iron from the viewpoint that it is steel plus graphite flakes.

Another case in point was a pair of contributions relating certain physical properties of steel to the analysis, and vice versa. One of the most difficult problems in the physical metallurgy of steel is the prediction of the physical properties which will result after heat treatment, and the effects of alloy content on these physical properties. For forgings of standard shape, certain standard compositions have been used widely, and physical property charts have been prepared which permit the engineer some degree of surety in his predictions.

However, the properties of steels for castings, which are usually made in relatively small quantities because of special requirements of shape and size, have not been standardized with regard to composition or heat treatment. An attempt to determine some of these relations was made by H. A. Schwartz and W. K. Bock of the National Malleable and Steel Castings Co. Many tests indicated that the relation between the tensile strength and elongation was approximately linear and confirmed the fact that the relation between Brinell hardness and tensile strength was also essentially linear. Based upon certain other reasonable assumptions these authors found it possible to determine the relation between the elongation and tensile strength for a steel of any possible combination of alloying elements. The actual data agree with derived curves sufficiently well to be used for practical purposes. Relationships between yield strength and tensile strength must depend on the hardenability of the steel and the microstructure after heat treatment. (A linear relation between tensile strength and elongation is in disagreement with the older data of Janitzky and Baeyertz; however, the latter did not consider differences in composition between the various steels examined.)

Such studies as this should permit better control of the final physical properties obtained in castings after heat treatment. Until we have a more thorough understanding of the mechanism of plastic deformation, prediction of the relations between the tensile properties must be based upon empirical studies of this nature.

Using somewhat similar empirical data, K. L. Clark and N. Kowall of the Physical Metallurgy Division of the Naval Research Laboratory derived a simple and rapid means of determining the carbon content of steel. Their suggested method was based on the assumption that the

hardness of the martensite formed on quenching low alloy steels is dependent *only* on the carbon content. Carbon content of a heat of steel may, therefore, be quickly determined by quenching a small sample and measuring the hardness. Data from more than 60 induction furnace heats gave a plot of Rockwell C hardness versus carbon content, in which the mean deviation was less than one point (0.01% carbon). Only a few determinations fell beyond the 0.02% carbon limit, within the range studied. Clark and Kowall's curve does not, however, agree very well with that obtained by Burns, Moore, and Archer, who studied the S.A.E. steels. Comparison of data from these two sources indicates that errors as large as 0.08% are possible.

There are, of course, other handy techniques for rapid carbon determination. In general, however, the equipment required is much more elaborate and therefore less favorable for use on the melting-shop floor. Carbon by hardness is certainly more accurate than estimating carbon from fracture especially in estimating carbon content of steels other than those habitually made by a given crew of men.

Shock Test

Two groups of metallurgists automatically separated themselves one afternoon at the A.I.M.E. convention. One contained those who have — for reasons they consider sufficient — crossed off the notched-bar test as too temperamental for engineering use, and who are excessively bored by the recurrent discussions of the second group. "Nice fellows, of course, but they have a single track mind." The second group cannot forget the teachings of centuries of experience, that a "tough" material is far better than a "brittle" one, and therefore they come back again and again to a search for a reliable test for "toughness". (This says nothing of a handful of men interested primarily in grinding up metal into powder, where obviously a brittle form is desirable, yet equally obviously a form that must be capable of being toughened after compacting into a useful part.)

Ordnance engineers have special demands for toughest materials, and an understandable desire to explain the mechanism of brittle fracture. The latest of a series of notable contributions from Watertown Arsenal is from Lt. J. H. Hollomon, who started out from the well-known paradox that two steels having identical properties when tested in simple tension at slow speeds and at room temperature may behave radically differently when tested in notched-bar impact. This difference in behavior has been correlated, qualitatively, with the differences in stress-strain characteristics as a function of temperature, strain rate and stress distribution (combined stress), as described in papers before last October's ASM Convention in Chicago. Lt. Hollomon emphasized that, because of the difference in conditions of the standard slow-speed, room-temperature, tensile tests and the notched-bar impact test, no direct correlation should exist between the results. A complete understanding of the test can only result from studies of the effects of variables of the test on plastic deformation and rupture. The interpretation which he presented was in effect a semi-quantitative extension of the more fundamental work of Ludwik in the 1920's.

The second of these two papers was based upon experiments performed at the Naval Research Laboratory and concerned some of the variables which could influence notched-bar impact results, such as breadth of specimen, type of notch, testing temperature, and speed of loading. The tests were performed by the standard methods and results expressed in terms of specific impact energy, based upon the "standard" impact specimen. One of the more important points brought out was that, for the range of steels which were investigated by the authors (Clarence E. Jackson, Myron A. Pugacz, and Frank S. McKenna), the specimens with V-notch appeared to be much more sensitive than the keyhole notch. A fairly successful attempt was made to correlate the *volume* of the material which had been deformed in the V-notch impact test with the notched-bar impact value. Some of the steels showed a good relation between the energy absorbed in impact and that absorbed in slow bend tests. Many other investigators, however, have pointed out that steels may be ductile with regard to the slow-bend tests and yet become embrittled when broken in impact.

These two papers should aid in a clearer understanding of notched-bar impact testing. In particular, it appears that the conditions of the test, being widely different from those of standard tensile tests, should receive the greatest consideration when interpreting the mechanism of impact fractures.

As was remarked at the outset, valuable metallurgical generalizations are difficult to establish in the first place — and it might now be added that they are subject to continual reappraisal as new data are uncovered. Among several papers dealing with the mechanical properties of non-ferrous materials, one assailed the view that coarse-grained metal has a lower creep rate than fine-grained metal. Perhaps the word

"metal" in the foregoing sentence should read "steel", for E. R. Parker and C. F. Riisness of General Electric Co. concluded from studies on copper that the creep rate at 200° C. is *not* a function of the grain size. It appeared at first that the cross section of the test specimen was important, but this proved to be the result of more rapid internal oxidation, accompanied by softening, when the diffusion distances were small.

Manganese and Hydrogen

Manganese may fairly be considered the one metal of greatest unknown possibilities. While its ores are relatively abundant and widely scattered, it has only recently been produced in quantity in pure enough form so that its unique properties could be utilized in parts for engineering and scientific machinery. Its allotropic modifications open up a tremendous field for heat treatment of its alloys — a field as yet almost totally unexplored. Credible rumors go around about interesting and valuable alloys already formulated, either for "hush-hush" war uses, or for post-war commercial gadgets.

An obvious question concerns the relative suitability of electrolytic and less pure forms of manganese. This applies to the minor uses; the major use — for the making of tonnage steel — will be decided in favor of ferromanganese purely on a cost basis. Interesting minor uses are for high manganese-iron alloys, and for non-ferrous alloys with manganese.

J. R. Long and T. R. Graham of the U. S. Bureau of Mines have added to the list of contributions from the Bureau on the last mentioned group of alloys, specifically comparing a 65% Cu, 10% Mn and 25% Zn with 70:30 cartridge brass. Their tests indicated that the copper-manganese-zinc alloy is generally superior to cartridge brass in its mechanical properties and resistance to stress corrosion.

A doubly interesting paper was by H. H. Uhlig of General Electric Co. and concerned the effect of hydrogen on several iron-manganese alloys and a Hadfield manganese steel. Low carbon alloys containing manganese up to about 20% are ductile (after vacuum treatment at 1800° F.), except those containing between 4 and 10% of manganese. Alloys in this range are brittle because they form a metastable alpha phase upon quenching. Furthermore, alloys containing more than 3% manganese are embrittled by treatment in hydrogen at 1800° F.; subsequent treatment at 1000° F. improves the ductility of all alloys which have been embrittled, whether this embrittlement is due to the formation of the metastable phase which transforms on tempering, or to the removal of hydrogen by the low temperature treatment.

Alloys of the high carbon type (Hadfield's 14% manganese steel) did not become embrittled after treatment in hydrogen at 1800° F., whereas the alloy if low in carbon was embrittled. The solubility of hydrogen at 1800° F. is appreciable in both, and the difference in behavior cannot be attributed to a lack of hydrogen; Doctor Uhlig suggested that it probably is associated with a less pronounced effect of dissolved hydrogen postulated for a face centered cubic structure. All of the steels investigated were subjected to cathodic hydrogen with a sulphuric acid electrolyte, and it was found that only those alloys containing 10 to 14% manganese were embrittled. Presumably only in this range was sufficient hydrogen absorbed. Alloys consisting primarily of the gamma or epsilon phase, as well as the low manganese alpha-phase alloys, do not take up appreciable amounts of cathodic hydrogen in sulphuric acid. The author pointed out in particular, that the impurities and surface conditions determine whether or not cathodic hydrogen will *enter* an alloy, and the structure and composition determine whether the hydrogen will *diffuse* further into the alloy.

C. E. Sims of Battelle Memorial Institute, who has long been interested in the subject of hydrogen embrittlement, led the discussion of this paper, which centered about the mechanism of embrittlement. In his opinion, localized regions (rifts) containing hydrogen under high pressure (suggested by Zappfe and Sims as the source of hydrogen embrittlement) can be present in the steel prior to any deformation. Uhlig, however, quoted a recent paper by U. R. Evans of England, who suggested that the effect of deformation was to decrease the solubility of hydrogen and thereby cause precipitation and embrittlement. Thus, the important question to be answered is whether the hydrogen embrittles the steel prior to deformation, or if some deformation is first necessary in order to precipitate the hydrogen.

Studies of the effect of hydrogen on the properties of steel are of prime importance. While damage by hydrogen has long been combatted in pickled articles — even thin sheets and wire — it recurs in a most exasperating way whenever American industry turns to the production of heavy forgings, such as gun tubes, ship shafting, and seamless pressure vessels. The type of research represented by this paper will contribute basic information for an understanding and control of the problem.

This reporter, being a "gadgeteer" at heart, was particularly fascinated by a group of papers dealing with the newer laboratory methods. S. E. Maddigan and B. R. Zimmerman of Chase Brass & Copper Co. presented a remarkable series of radio-micrographs of copper alloys, which not only exhibited high resolution, but delineated structural features difficult or impossible to record by ordinary photomicrography. For example, coring in a cast bronze appeared as a gradation of shade usually masked by necessary etching, shrinkage porosity was revealed in depth as well as in the cross section, and phases, hard to distinguish, were clearly differentiated by their variable ability to transmit X-rays. Indeed, the authors have used X-rays of selected characteristic wave lengths both to attain the desired degree of contrast in their pictures and to differentiate among phases.

Last fall F. Keller and A. H. Geisler, in a discussion on the electron microscope, introduced some results obtained in Aluminum Research Laboratories with the oxide-film technique of preparing specimens for examination. They now describe the technique in full, with many beautiful examples. Aluminum, of all the common metals, is probably the most susceptible to the method, which consists essentially in using the oxide film that forms on the polished and etched surface of the metal as a transparent replica. The metal is removed by chemical means leaving the thin oxide film to which may be attached such particles of insoluble matter as were adjacent to the surface. The electron-micrograph then shows both the contour of the surface and the silhouette of any attached or embedded particles. Photographs at magnifications as high as 40,000 diameters exhibit remarkable resolution, showing not only the presence but the shapes of extremely fine precipitates.

Oxide coatings on metals have generally been thought of as diffusion layers. J. D. Edwards and F. Keller find evidence that the oxide coating on aluminum grows beyond a certain thickness, quickly attained in the air, only when the coating is sufficiently porous to permit the travel of oxygen to the metal-oxide interface. These authors have developed metallographic techniques that reveal an amazing amount of detail in cross sections of very thin oxide layers. Probably some sort of record has been broken by one of their electron microscope photographs which, at a magnification of 110,000 diameters, exhibits satisfying resolution. The pictures show that anodically formed oxide coatings are composed of what appear to be fibers or tubes of alumina oriented perpendicular to the metal surface.

Cartridge Brass

It is natural that the war-time interest in cartridge brass should stimulate research upon this material; three papers were submitted from as many laboratories. Because of the simplicity of its structure this alloy has long served those intent upon the pursuit of the fundamentals of recrystallization, and several recrystallization diagrams representing the relationships among degree of deformation, temperature of annealing and grain size have been published, starting with the earliest scientific literature from the brass industry.

It has also been known that the *time* of annealing should be regarded as a controlling variable, but comprehensive data have been lacking. At the present meeting R. S. French of Bridgeport Brass Co. remedied this gap in published information, and exhibited "space diagrams" including the time variable. His observations were made under operating conditions, which may lead some to distrust their precision, but the contribution of these much-needed data will be welcomed, none the less.

Another feature of the recrystallization of cartridge brass that has been a subject of interest for some time is the development of preferred orientations. H. L. Burghoff and J. S. Porter of Chase Brass & Copper Co. show that, in annealed brass wire, the degree of preference is controlled by the last two anneals and the intermediate cold reduction. Pronounced fibering is favored by low temperature in the semi-final anneal, drastic cold deformation and a high temperature in the final anneal. They point out that the presence of a preferred orientation can be detected from characteristic orientations of annealing twins, and they have demonstrated that fibering is to be associated with high yield and tensile strengths.

Some years ago a Chinese student who had come to Carnegie Institute of Technology for graduate study returned to partake in the defense of his homeland, carrying with him notes on his American researches. Five years had passed without communication, when another Chinese appeared with the sheaf of notes, carried out of China as a part of his meagre baggage allowance. The data that traveled this adventurous route have now been presented in a paper by Shueling Woo, C. S. Barrett and R. F. Mehl describing the orientations developed in diffusion layers in brass, and which are found to coincide with those discovered in studies of the Widmanstätten structure in the same system.

Powder Metals

A dozen contributions on the above subject formed the basis of an all-day meeting of "The Powder Metallurgy Committee". After listening to them it would be difficult to say whether any fundamental advances in powder metallurgy have been made in the last two years. Feverish activity by powder producers and increased production by fabricators can be reported. Likewise increased awareness of what is old and what is new to the field is evident, yet the same can be said of many a manufacturer who is or contemplates going into precision casting. Probably the really new developments are being hid until after the war.

In consequence, one must beware of overselling the future possibilities of the powder technique. It should be evident that powder metallurgy has a definite yet limited field of application as a competitive technique in saving machining costs. To A. J. Langhammer, of Chrysler's Amplex Division, who entered the discussion, this view is no doubt too pessimistic. After he had listed all the new products his organization has recently made, many realized for the first time how much bar stock is actually being made from powders, and furthermore how often it is economical to shape a piece three-quarters of the way by powder metallurgy and finish it by customary machining methods. Undercuts and threads are cases in point.

Those present at the symposium who feared that this would be another meeting rich in generalities were agreeably surprised by F. V. Lenel of the Moraine Products Division of General Motors, who took one product — iron pole pieces for direct current motors — and described all phases of research, development and production to show the advantages and limitations of powder metallurgy. Although the magnetic properties of cores made from laminated steel are better than those made from iron powder by about 20%, the saving in labor and material for even complicated shapes makes the application feasible. Pressing in production machinery and sintering for 1½ to 3 hr. at 2400° F. gives a product with 95% of theoretical density. Lenel believes that electrolytic iron gives the best results, but other iron powders can sometimes be used.

Some commercial limitations were also described by C. R. Fulton of General Electric Co. in a discussion of sintered magnets. Alnico magnets larger than 2 oz. can be made more cheaply by casting than by pressing and sintering. Smaller ones can be made at a higher rate, with better magnetic properties, and to greater precision from powder. Of interest to many was the simultaneous sintering of Alnico to iron shafting.

Much of the other discussion concerned parts intended for rubbing contact, such as bearings, clutch plates, and electrical contactors (brushes). In his paper on porous bearings W. R. Toeplitz, of Bound Brook Oil-Less Bearing Co., emphasized the applicability of porous bearings where the pressure times velocity does not exceed 50,000. Superior bearings, according to him, have a density of 6.2 to 6.8, hold no more than 25% by volume of oil (preferably of higher viscosity than the common types used in ordinary lubrication).

R. R. Hoffman of the Keystone Carbon Co. discussed the methods of manufacture and control of carbon-rich and metal-rich brushes used in electrical machinery. In many instances electrical, thermal and mechanical requirements are such that a number of small brushes are more effective than large composite ones. Here, as in the electrical contact and the carbide field, it is sometimes more economical to presinter or sinter a large block and to machine smaller parts therefrom, than to use pill presses.

From this paper, as well as from E. I. Larson's of the P. R. Mallory Co. on electrical contacts, and of C. T. Cox's of the S. K. Wellman Co. on friction material, it was evident that the manufacturer of such specialized parts is as much concerned with complicated physical testing to control his product, as he is with its metallurgy. To C. T. Cox we are indebted for pointing out how slight variations in the composition of brake material, comprising copper, tin, lead, iron, graphite and silicon, affect the coefficient of friction, wear resistance and noise when rubbing against steel. Only through laboratory dynamometer and field service tests is real control obtainable. A. J. Langhammer's mention of large products was supplemented by Cox, who described friction plates 1000 sq.in. in area.

There is little space available in this review to comment on the more extensive metallographic aspects of the problems under review, yet as more such papers become available it is increasingly evident that the metallurgist will find the field well worth closer attention. In particular the role of dissolved, adsorbed and absorbed oxygen has been too leisurely disregarded by the powder metallurgist. C. Balke of Fansteel Products Corp., for example, believes that the metallurgist can make a *better* product from powder than by melting if he carefully eliminates all oxygen and oxides from the raw material and its processing. As examples he cited his own experiments with iron and with tantalum.

Brief excerpts from the 1944 Henry Marion Howe Memorial Lecture, delivered before the American Institute of Mining & Metallurgical Engineers by James T. MacKenzie, chief metallurgist of American Cast Iron Pipe Co.

Gray Iron— Steel Plus Graphite

AT THE TURN of the century, foundrymen believed that cast iron was a metal entirely different from steel. Henry Marion Howe was of the contrary opinion, stating, "Each member of the gray cast iron series consists of the metallic matrix approximately equivalent to that member of the steel-white-cast-iron series to which it corresponds in percentage of combined carbon with its continuity broken up by masses of graphite . . . . ." He went on to say, "Minor structural differences are indeed to be expected, because of the difference in the conditions under which these constituents are generated. The steel of most micrographs has been either forged or at least treated thermally in such a way as to give a new structure radically different from that which formed during the initial solidification, whereas the cast irons have not. Hence what we see in the steels is a transformation structure, but in the cast irons a solidification structure."

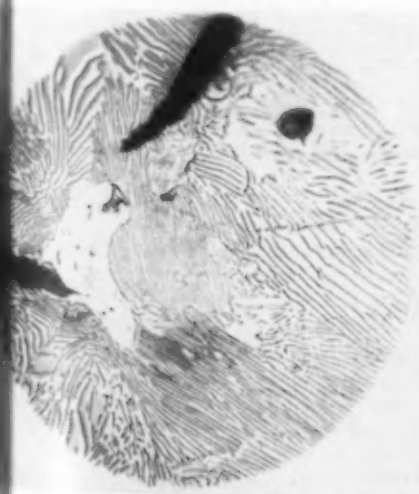
Today large tonnages of cast iron are heat treated — some annealed, some normalized, some quenched and drawn. Figures 1 and 2 are examples, magnified 1000 diameters, from the commercial production of 3½-in. diameter bar stock of low total carbon iron (2.4% C). The great improvement in properties noted in the captions is due to transformation of the matrix, since the graphite was changed practically none at all.

The mechanism of the formation of graphite has been concisely stated by Alfred Boyles. The flakes do not begin to form until the eutectic begins to freeze, and they are thus restricted by the size and distribution of the already solidified dendrites. They grow radially from crystallization centers outward in the form of a rosette or whorl formation.

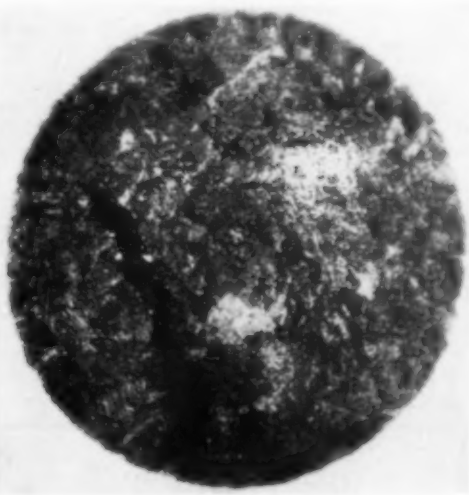
We have verified this statement by obtaining a space model by taking a series of micros after repeated polishings, and stacked the plates with proper spacing between them. Clay models were then constructed and set up in actual space relationships, as shown in Fig. 3.

It is obvious that they do not completely envelop the grains of matrix, and that cast iron only becomes permeable at a thickness which is governed by the greatest length of graphite flakes. "Porosity" is due to flaws in the casting — never to the metal structure. Thousands of tests on

As Cast Structure; Coarse Pearlite
Tensile strength 39,000 psi.
Brinell hardness 235 to 255



Normalized at 1700° F.
Tensile strength 53,000
Brinell hardness 285



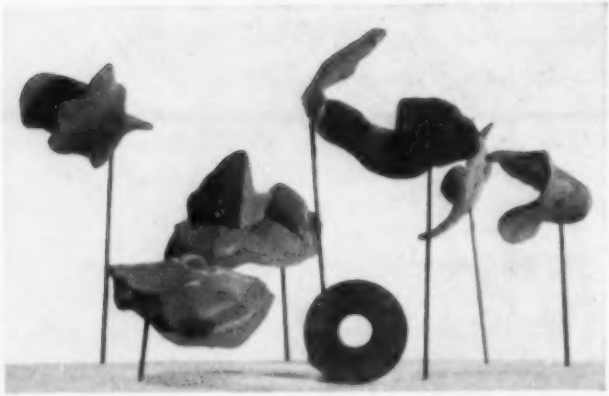


Fig. 3—Space Relationships of Graphite Flakes (Magnified About 150 Dia.) From a Piece of Gray Iron. Standard inch included for scale

cast iron pipe have proved this beyond a doubt. I cite but one: A 100-ft. line of 6-in. pipe of different classes with wall thicknesses varying from 0.30 to 0.45 in. was kept under 800-psi. gasoline pressure for 233 days. Variation in pressure rose and fell in exact proportion to the temperature for the whole time — even the slightest seepage would have been evident.

Graphite formation is accompanied by an expansion. While this tends to reduce shrinkage, it cannot eliminate it, since the expansion of the first shell (and each succeeding layer, as it solidifies) tends to enlarge the mold. At the end there is not enough still-liquid metal to fill, and a pipe must result unless the cavity is fed. An erroneous idea is that this expansion causes the metal to reproduce more accurately the shape of the pattern. In fact this is solely a function of the "fluidity" of the metal, giving the word the foundryman's definition. (By the physicist's definition, fluidity of the metal is practically zero by the time the graphite appears.) The idea probably started from the exquisite detail of the cast iron art ware of the early 19th century, but having the misfortune of breaking one of those pieces awhile back, it was some secret satisfaction to find it white!

Mechanical Properties — Mathematicians and testing engineers have long been interested in the discrepancy between the bending strength as measured on a beam specimen and as calculated from the tensile strength on the conventional beam formula. It has been determined that this arises principally from the fact that the formula is based on the supposition that the neutral axis remains stationary during flexure. In 1888 Bach established the fact that the neutral axis of a certain beam was displaced toward the compression side, so there was actually 38% more metal in tension than in compression at the instant of fracture (see Fig. 4). His work on combined tension and bending is the foundation of the modern design of cast iron pipe. Some evidence is available to support the view that gray iron, under test, acts as steel with a multitude of internal cavities; at any rate designers must recognize that it departs clearly from the assumption of the theory on which conventional mechanics is based, namely, homogeneity, isotropy, and elasticity.

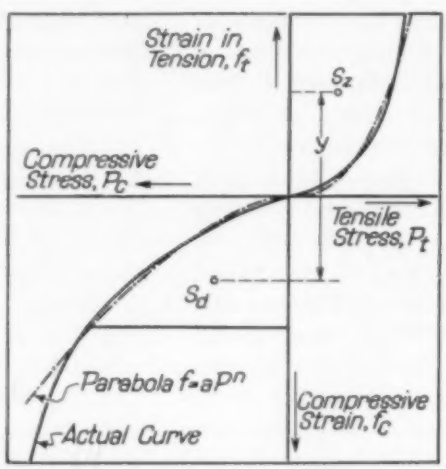


Fig. 4—Bach's Stress-Strain Diagram for Cast Iron in Bending

a and *n* are constants varying with the nature of the iron; *a* usually ranges between $0.5 \cdot 10^{-6}$ and $8 \cdot 10^{-6}$, while *n* ranges between 1.15 and 1.60

A rich fund of data on the mechanical property of irons with varying percentages of graphite is found in the 1933 *Transactions* of the American Society for Testing Materials. [Approximate relations have been scaled by the

(Continued on page 714)

Quantitative Influence of Graphite on Properties of Gray Iron

[Approximations from Mr. MacKenzie's graphs]

Percent Graphite	Tensile Strength	Ratios			Load at Given Deflection	
		Modulus of Rupture to Tensile Strength	Compressive Strength to Tensile Strength	Shearing Strength to Tensile Strength	0.15 In.	0.20 In.
1.6	57,500	1.85	2.6	1.0	2450	3000
2.0	46,000	2.0	3.0	1.15	2100	2550
2.4	35,000	2.0 to 2.2	3.2 to 3.6	1.3	1850	2150
2.8	25,000	2.1 to 2.4	3.4 to 4.4	1.4 to 1.5	1500	1750
3.2	17,500	2.2 to 2.7	4.4±	1.7	700	900

Now is the time to think about Molybdenum...

With both molybdenum and tungsten again available for use in high speed steel, consideration of their comparative performance is timely.

Before the war, a careful recording of comparative tests converted many users and tool makers to molybdenum high speed steel. During the tungsten shortage, when use of a high percentage of molybdenum types became mandatory, most users could not watch the performance of their tools carefully enough to draw conclusions on their respective merits.

Reports from large tool producers and users confirm that molybdenum high speed steels, when properly heat treated, perform at least as well under different kinds of shop conditions as the tungsten types which they replace.

Given equal performance on any particular type of work, an investigation of the saving in machining cost effected by molybdenum steels will prove well worth while.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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Climax Molybdenum Company

500 Fifth Avenue · New York City

MOLY

Personals

L. E. DAY, formerly with the Carrier Corp., Syracuse, N. Y., is now in the Design Engineering Division of the Westinghouse Electric Elevator Co., Jersey City, N. J.

Promoted by Climax Molybdenum Co.: JOHN F. ROBB to manager of the Pittsburgh district.

CLYDE WILLIAMS, director of the Battelle Memorial Institute, Columbus, Ohio, has been engaged by the Association of American Railroads as technical consultant to advise the railroad industry on research matters.

L. S. ROSS has transferred from the Saginaw Steering Gear Division of General Motors Corp., to the Diesel Equipment Division at Grand Rapids, Mich., as foreman in production of miscellaneous parts.

HENRY H. ZIESING, former general sales manager, has bee elected vice-president in charge sales of the Midvale Co., Philade phia, succeeding STUART HAZL WOOD, who has resigned

HERBERT J. FRENCH, past pres dent, assistant manager of th Development and Research Div sion, International Nickel Co., an formerly chief of the Metallurgica and Conservation Branch of th Steel Division, War Productio Board, has been named assistan director for raw materials an facilities of the Steel Division.

L. H. BRANDT, formerly wit E. I. du Pont de Nemours & Co., i now connected with the Technica Service Department of the Pennsyl vania Salt Mfg. Co., Philadelphia

S. L. FEDUSKA, research me allurgist of Indiana Steel Product Co., Valparaiso, Ind., has been ap pointed plant metallurgist in charg of foundry, heat treating and forg ing department.

W. A. SHERRER, formerly wit the H. W. Dietert Co., is now meta lurgical laboratory coordinator Engineering Department, Brewste Aeronautical Corp., Johnsville, Pa

LORAINE M. BUHLER, Colorad School of Mines '44, is now em ployed at the research laboratorie of the Linde Air Products Co Tonawanda, N. Y.

ROBERT REED DENISON is no employed by the Sheffield Ste Corp., Houston, Texas.

C. ROBERT TALMAGE, former chief engineer, A. Robert Snyde Co., Dayton, Ohio, is now produ tion manager, Manning Bowman Co., Meriden, Conn.

VIRGIL SHELTON, former with the Bowdil Co. of Canto Ohio, is now employed by Com monwealth Aircraft, Inc. of Kansa City, as a machine shop foreman

JARRED M. BARRON, former with the American Rolling Mill Co is now a captain with the Army Ordnance Department, station overseas.

Promoted by Allegheny Ludlum Steel Corp.: W. G. MCFADDEN, from assistant to district sales manage of the Chicago Office.

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...Correctly Poured
and Heat Treated

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If your equipment is operating under difficult conditions of corrosion, high temperatures and abrasion, investigate the use of chrome-iron or chrome-nickel castings to meet these conditions. For tubular products requiring a denser, stronger, more uniform metal, consider the use of DURASPUN CENTRIFUGAL CASTINGS.

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Developing secret military devices is a big job but big forces are busy on it, day and night.

Concentrating on this job are more than 7000 people in the Bell Telephone Laboratories. Its scientists and engineers and their skilled associates form a highly organized team, experienced in working things out.

Today's work for war had its beginning many years ago when these laboratories were founded as part of the Bell System's service to the public.

BELL TELEPHONE SYSTEM

Personals

Appointed to various industry advisory committees of the War Production Board: LEO B. GRANT, Dow Chemical Co., Midland, Mich., to the Magnesium Sand Casting Industry Advisory Committee; ROBERT CHESTNUT, Aluminum Co. of America, Inc., Edgewater, N. J., to the Screw Machine Products Industry Advisory Committee; DONALD McQUILLAN, Spartan Saw Works, Springfield, Mass., to the Metal Cutting Hack and Band Saw Industry Advisory Committee; F. H. RAYFIELD, vice-president, Potter and Rayfield, Inc., Atlanta, Ga., to the Gray Iron Castings Industry Advisory Committee.

Appointed sales research engineer for Wickwire Spencer Steel Co., New York City: H. C. ALLINGTON, formerly district manager of the Logan-Allington Co., Inc.

CARL O. SUNDBERG has taken leave of absence from his position as associate engineer at the St. Louis Ordnance District to accept a commission as an ensign in the U.S.N.R., and is attending the General Ordnance School in the Navy Yard, Washington, D. C.

WALTER S. MACNABB has been appointed division superintendent of blast furnaces, Gary Works, Carnegie-Illinois Steel Corp.

FRANK J. STANLEY has been appointed plant manager of the Lebanon Steel Foundry, Lebanon, Pa., succeeding HENRY D. PHILLIPS, who has resigned to accept a commission in the U. S. Navy. L. G. MILLER, formerly chief inspector and assistant to the plant manager, assumes Mr. Stanley's former position of plant superintendent.

SCOTT W. SMITH, physicist with the Kelley-Koett Mfg. Co., Covington, Ky., has been appointed to an advisory committee conducting research on fluoroscopic methods of inspection of metallic materials for the National Academy of Sciences and the National Research Council.

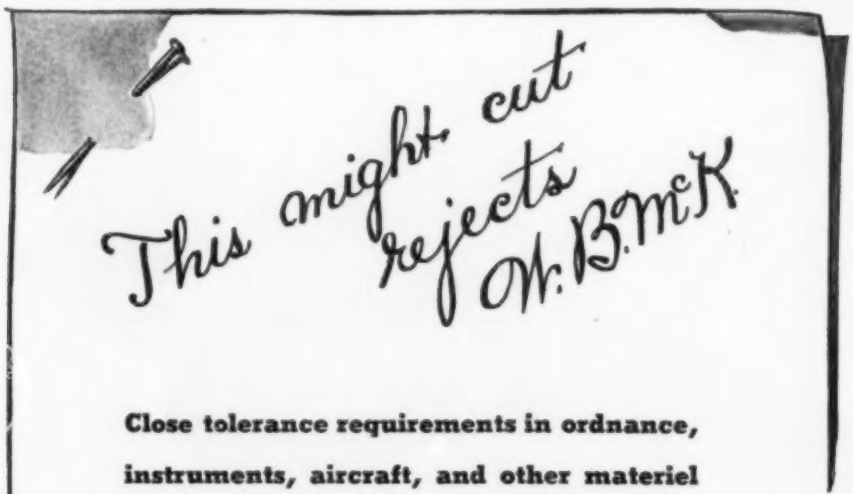
Promoted by Climax Molybdenum Co.: PAUL M. SNYDER, formerly in charge of sales and development work in the Canton area, to sales manager of the Company with headquarters in Canton, Ohio.

RICHARD G. BYRNE, formerly on the advertising and production staff of *Metal Progress*, now serving with the U. S. Navy in the Pacific, has been promoted in rank from ensign to lieutenant (jg).

STANLEY M. COOPER, vice-president of the Fafnir Bearing Co., New Britain, Conn., has been appointed an assistant director of the Tools Division, War Production Board.

L. E. CREIGHTON has resigned as chief of the Alloy Steel Branch of the Steel Division, War Production Board, and is succeeded by S. A. CRABTREE of Chicago, Ill.

SAMUEL L. CASE, formerly technical advisor, Jones & Laughlin Steel Corp., Pittsburgh, is now associated with Battelle Memorial Institute as a research metallurgist.



Close tolerance requirements in ordnance, instruments, aircraft, and other materiel add a function of increasing importance for KSG Silica Gel Dryers. The dehydration of compressed air for surface inspection of interiors and exteriors is a case in point.

Available in a wide range of capacities, starting at 20 cfm and built for continuous or intermittent operation as may be required, KSG Silica Gel Dryers meet every industrial drying need.

For descriptive bulletins, specific information or engineering assistance, address The C. M. Kemp Mfg. Company, 405 E. Oliver St., Baltimore-2, Md.

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Q *Which x-ray film is first choice for use with calcium tungstate screens?*

A *Kodak's Type "F"*

Kodak Industrial X-ray Film, TYPE F, is especially designed for use with calcium tungstate intensifying screens, with which, because of its high sensitivity to the fluorescent light emitted by the screens, it provides the highest available speed and contrast. It is first choice in all work where the intensification of calcium tungstate screens is necessary to reduce exposures to reasonable times—such as in the radiographic examination of thick steel parts. It may also be used with lead-foil screens, with which it provides medium contrast, in either x-ray or gamma-ray exposures.

Characteristic Curve, Kodak Industrial X-ray Film, Type F, with double intensifying screens of calcium tungstate. The curve's steepness at a given density indicates contrast.

Development: 5 minutes, at 68°F, in Kodalk X-ray Developer.

Kodak Provides the 4 Types of Film Needed in Industrial Radiography

In addition to TYPE F . . .

Kodak Industrial X-ray Film, Type K
. . . primarily for gamma radiography, with lead-foil screens, of heavy steel parts . . . or lighter parts at lower voltages.

Kodak Industrial X-ray Film, Type M
. . . "made to order" for higher voltages, light alloys, and critical inspection.

Kodak Industrial X-ray Film, Type A
. . . primarily for light alloys at lower voltages and million-volt radiography of thick steel parts.

EASTMAN KODAK COMPANY
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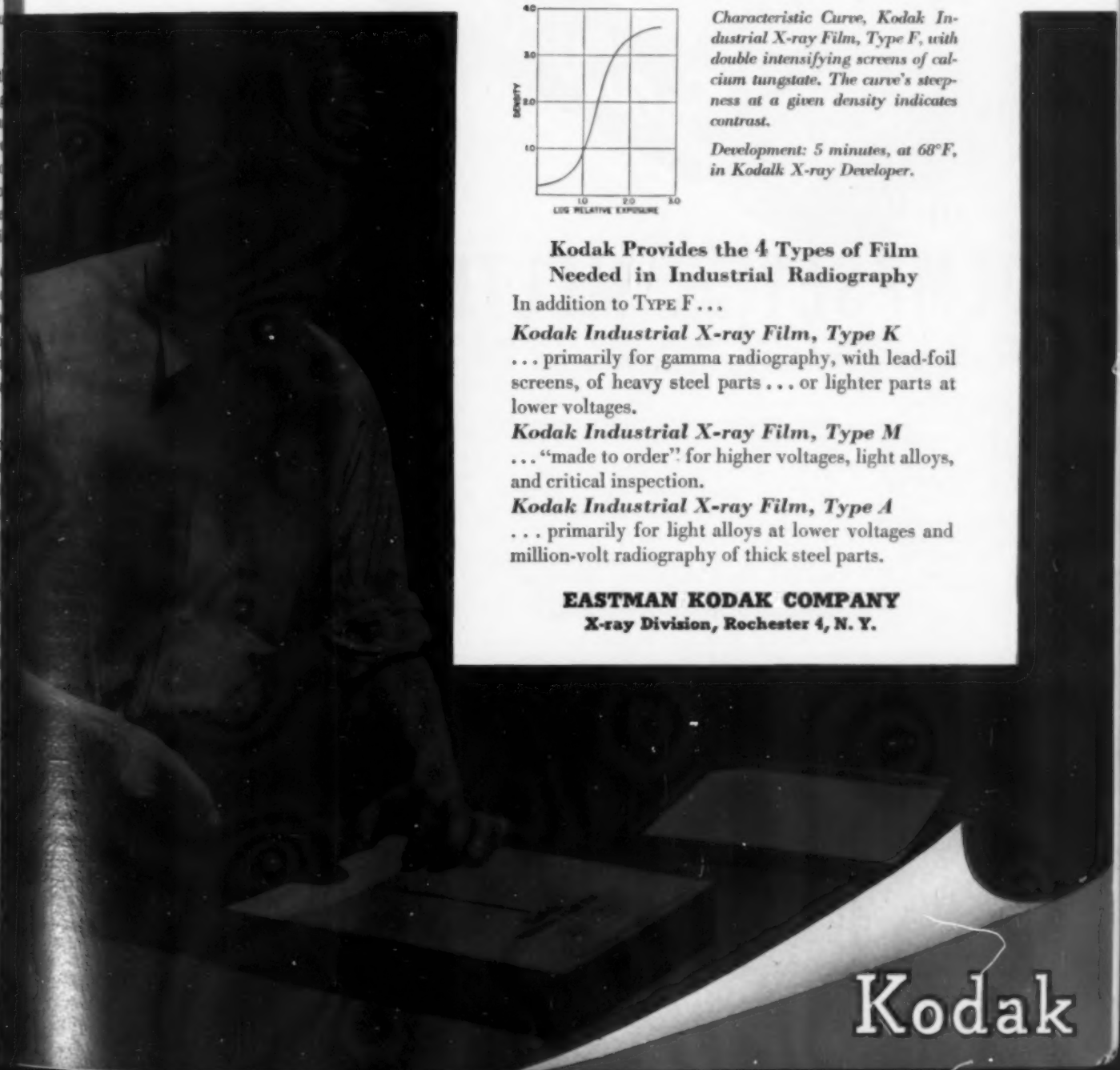

Brazed Cutters*

By W. A. Johnson

IN TOOLING UP for war production the Tractor Works of International Harvester Co. was literally forced to reclaim so-called scrap tools, since the requirements for cutters were so varied and extensive and deliveries of new tools were impossibly long. Fortunately we had studied the problem of reclamation of perishable tools by low temperature brazing for at least two years, and every possible talent was focused on the problem and we are rather proud of our success.

Continuous efforts have been made to find a hard metal whose melting point is below the tempering temperature of high speed steel. This could then be used to build up or replace a worn or missing tooth on a cutting tool. Unfortunately this metal is not known.

So we perfected our technique with the low temperature brazing process, and have put cutting tools back to use for a normal life expectancy. Cracked slitting saws, broken milling cutters, broken flat, round and multiple spline and keyway broaches, extension reamers and drills made from two short ones, two short tool bits butt brazed together, repaired broken dovetails on forming tools, and many other examples of this method of tool reclaiming have been realities at Tractor Works.

Steps common to this type of tool reclaiming are:

1. Preparing the surfaces to be joined. If an even break has occurred, we find it better not to grind the joint ends.
2. Clean surfaces thoroughly of dirt with carbon tetrachloride using a soft bristle brush.
3. Coat the surfaces to be brazed with autochemic flux.
4. Preheat to 700° F.
5. Apply an oxy-acetylene torch to the joint ends.
6. Apply brazing material until it flows freely through the joint.
7. Grind or file excess material.
8. Sharpen.

Preheating is necessary to avoid temperature checks near the brazed joint. It is also advisable to put the brazed tool back into the preheating furnace, equalize the temperature, and then cool in lime or mica dust.

Several commercial brazing materials are available, either copper-base or silver-base alloys. Suitable alloys melt at 1175 to 1300° F., close to or at the drawing temperature of high speed, so the repair man must be very careful in manipulating his welding torch. He must not "soak" the heat. He must work from the center of the mass toward the edge. He must use the welding wire as a thermometer. The flux must be entirely liquid below the flow point of the brazing alloy.

Most tools require the use of an alignment fixture, which need not be elaborate, but must be accurate. The strength of a correctly brazed joint depends upon its thickness. The strongest joint thickness seems to be 0.0015 in.

Milling cutters — a bottleneck in one of our war contracts — have been made by brazing hardened blades into a heat treated body made of machine steel. Such cutters are of mill type, backed-off type, plain, side and form milling cutters, and have *(Cont. on p. 712)*

*Abstracted from "Reclamation of Perishable Tools by Low Temperature Brazing", *The Welding Journal*, January 1944, page 43.

DEMPSEY CHIP and DROSS MELTERS

Recover Primary Metals at 85-95%

DEMPSEY FURNACES
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Wright Aeronautical

More and more, war producing manufacturers, realizing the necessity for reclaiming scrap in as pure a form as possible, are looking to Dempsey for chip and dross melters which will do this vital job profitably and speedily. Aluminum chips and dross, for example, are being converted into primary metal for the feverishly producing airplane industry at a recovery rate of 85-95%.

Oil, gas or coke fired, Dempsey Melters provide faster melting time, simple single-valve control, easy control of tapping speed and may be equipped with mechanical puddlers which reduce oxidization loss to a minimum.

There is a Dempsey Furnace for every heat treating need.

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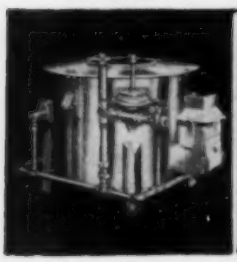
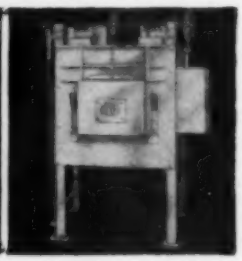
Pot Furnace

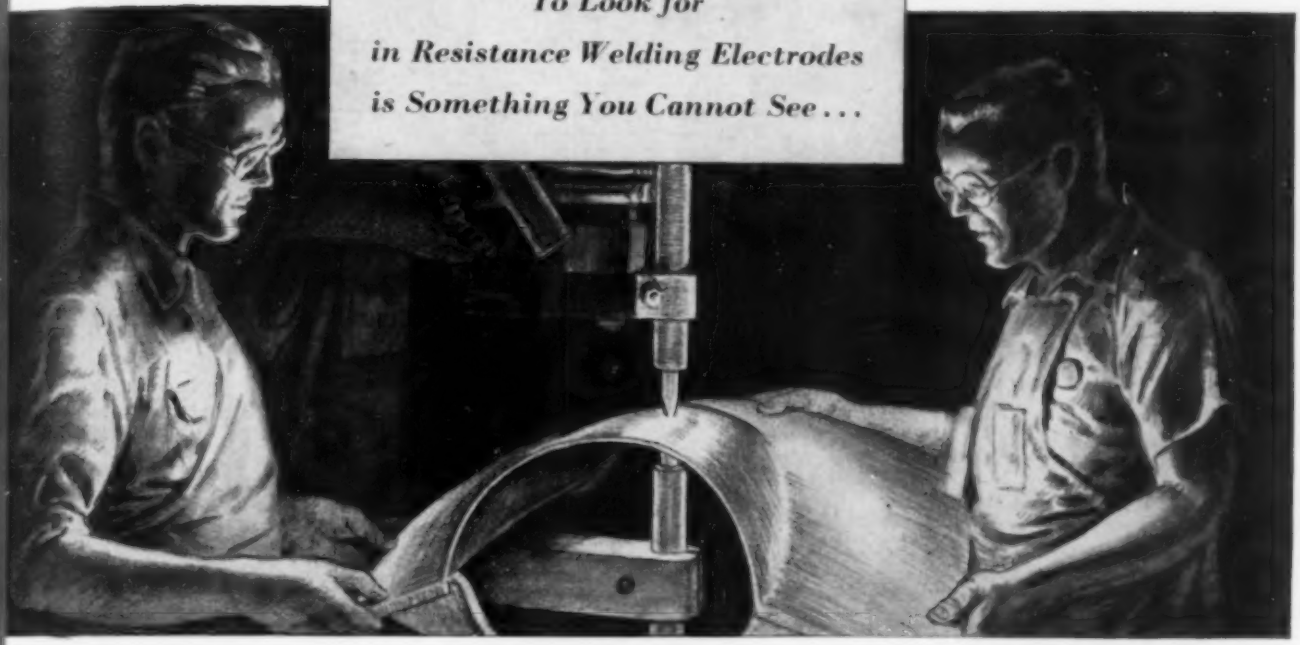


Continuous Heat, Quench and Draw Unit

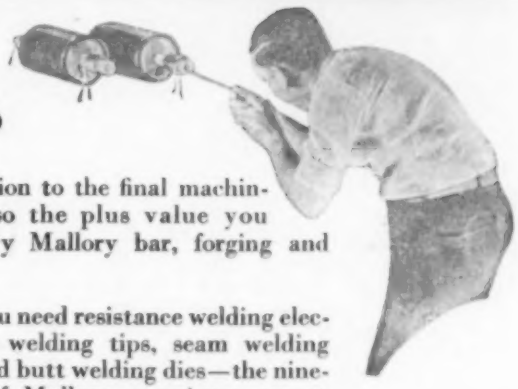
Semi-Muffle Furnace



The Most Important Thing
To Look for
in Resistance Welding Electrodes
is Something You Cannot See . . .



Mallory Metallurgical Knowledge . . . Behind the Faster, Better Welding Job



Speed—without loss of quality—is the watchword of every war plant. Mallory sets the pace with dependable, long-life resistance welding electrodes that produce better welds in fewer man hours.

Standard Mallory electrodes save the costly delays formerly involved in producing special tips. Mallory alloys—Elkaloy*A, Mallory 3* Metal, Elkonite*—greatly reduce "down time" for redressing and replacement.

Back of this combination of speed and excellence lies Mallory metallurgical knowledge. It extends through every step of electrode production, from the exact proportioning of the composition to the final machining. It is also the plus value you get in every Mallory bar, forging and casting.

Whenever you need resistance welding electrodes—spot welding tips, seam welding rolls, flash and butt welding dies—the nineteen years of Mallory experience are at your service. Mallory experience can help you determine the right size and contour of electrode for the job, and the type of alloy best suited for its requirements. It can lead, as it has frequently led before, to stronger, lighter, more easily fabricated products at lower cost.

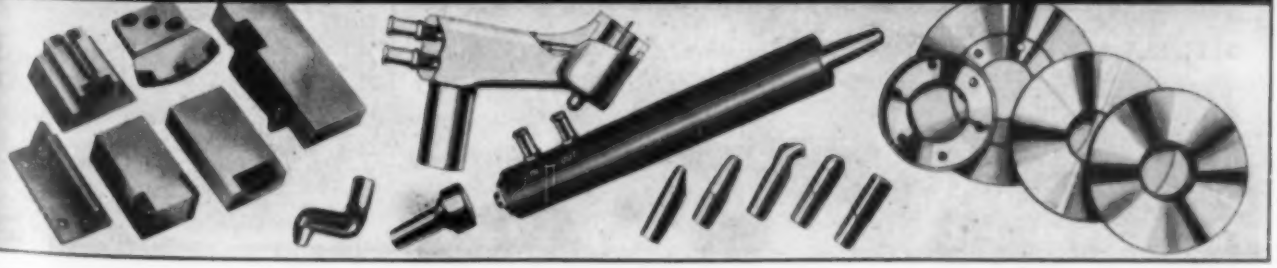
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

Invest in Victory —Buy More War Bonds

*Reg. U. S. Pat. Off. for metal compositions

P. R. MALLORY & CO. Inc

MALLORY *Standardized Resistance Welding Electrodes*



Although principally designed to provide an inexpensive unit for quick and convenient drying of electrodes in connection with the determination of lead as lead dioxide, this infra red drying oven has a wide variety of other applications. For example, it is excellently suited for such operations as evaporating, drying precipitates, paraffin melting, drying solids, etc. Drying efficiency is well illustrated by the fact that lead dioxide is thoroughly dried in one to two minutes.

The oven consists of a cylindrical case containing a General Electric R-40, 250 watt drying lamp with self reflector, a hinged, chromium plated, hemispherical dome, a chromium plated perforated shelf and an on-off switch mounted on the case. The reflector contained within the drying lamp reflects the radiant heat upward thus directing all energy to the working area of the oven. Further concentration of heat is accomplished by the chromium plated dome which acts as a highly effective heat reflector so reducing to a minimum heat loss by radiation. By means of this design a maximum temperature of approximately 500° F is developed within ten minutes. The fast upward flow of air induced by the open bottom and vent in dome also contributes greatly to the high drying rate of this oven. Average service life of the infra red drying lamps is 5000 hours.

Overall dimensions: height, 13½ inches; diameter, 6½ inches. Inside dimensions: height from top of perforated shelf to top of dome, 5¼ inches; diameter, 5⅞ inches. Electrodes having a total height exceeding 5¼ inches can be placed in the oven by permitting the electrode stems to project out of the vent hole in the dome.

S-64050 Sargent Infra Red Drying Oven—Complete with General Electric R-40, 250 watt drying lamp, perforated shelf and cord and plug. For operation from standard 115 volt A.C. or D.C. circuits.....$18.00

S-44200 Infra Red Drying Lamp only, with Self Reflector, General Electric R-40, 250 watt. Each.....$1.75

E. H. SARGENT & CO., 155-165 East Superior St., Chicago 11, Ill.

Michigan Division: 1959 East Jefferson, Detroit 7, Michigan

SARGENT

SCIENTIFIC LABORATORY SUPPLIES

Brazed Cutters

(Cont. from p. 710) the same life as "new" tools. Details of this fabrication process follow:

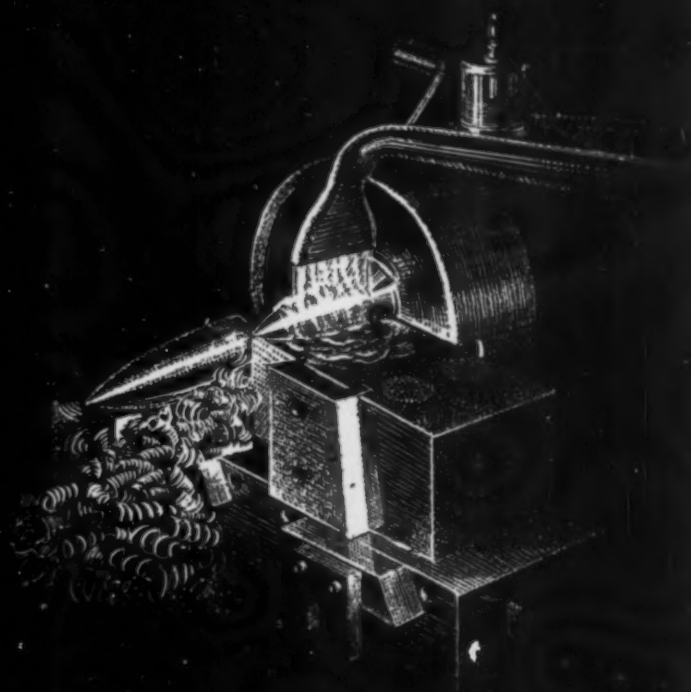
We machine a milling cutter hub from a mild alloy steel in a suitable manner for receiving the hardened blades. Blades are then peened into place and brazed. Scrap cutter blades can be used as well as new ones. After brazing in place the cutter is then ground in the conventional manner. When making a backed-off form milling cutter, it is necessary to form-grind blades with a straight back-off so all teeth will do their required work. This form grinding is not a simple process; it can be done by simple template type fixture.

There are several advantages in making a milling cutter by this method:

1. More blades can be attached per inch of circumference — thus, less chip load per tooth.
2. Increased feeds and speeds can be handled by these additional blades — thus increased production.
3. It is versatile.
4. You can help yourself when "store" cutters are not available.
5. A stronger cutter results.
6. Many shops do not have back-off lathes, yet these cutters can be made without one. You can readily see the advantage of this process.
7. We believe that the fabrication of cutters by this method could be as economical as the conventional manner.

Finally I wish to emphasize the importance of accurate fixtures. The use of stock, mill run angle plates and clamps is not sufficient for use by a welder in repairing precision made cutting tools. We have found that approximately eight or ten universal fixtures are all that is necessary for the welder to have in repairing the average cutting tool used in an industrial plant engaged in the manufacture of automobiles, trucks or tractors. These fixtures should be constructed with positive clamping devices in the lower section and spring plunger floating locating devices in the upper half. This design is necessary so as to insure the correct joint thickness in the shortest period of brazing heat. Elaborate, expensive and costly fixtures are not necessary, but they must be accurate, universal and constructed of good, well-selected materials.

EXAMPLE OF *Service*:



A manufacturer now turning out shell casings asked one of our Cities Service Lubrication Engineers to make a survey of his machining operations . . . Our engineer recommended certain changes, including the use of a new *transparent* blend of Cities Service Cutting Oil, which permits full visibility during the cutting operation. RESULTS: Tool life increased by 20% . . . cutting oil cost cut 25% . . . production efficiency and quality of work both improved.

More and more, it's service that counts . . .

and *Cities Service* means good service!

CITIES SERVICE OILS — ONCE-ALWAYS

CITIES SERVICE OIL COMPANY

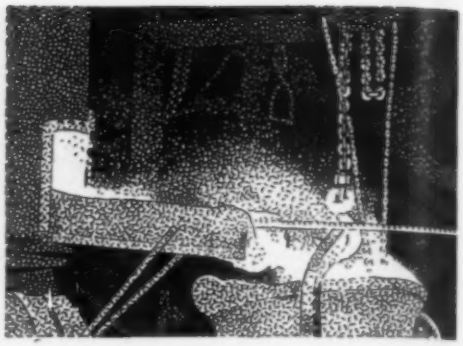
ARKANSAS FUEL OIL COMPANY

Gray Iron

(Continued from page 704)

Editor from Mr. MacKenzie's diagrams, and listed in the table at bottom of page 704.] While graphite reduces the bending strength it does not reduce it as rapidly as the tensile strength. Compare irons at the extreme ends of the survey; one has 51,000 psi. tensile strength and 92,500 modulus of rupture, whereas the other has 20,000 psi. tensile strength and 49,000 modulus of rupture.

A measure of stiffness called "secant modulus of elasticity" has been widely used by American engineers, being merely a substitution of the load and deflection in the conventional beam formula. "Secant modulus of elasticity" has very little relation to the true modulus of elasticity of the mathematicians. On the other hand, a direct quantity, long used in cast iron pipe specifications, and quite simple when using a standard test bar, is the load at a certain deflection. This can be read directly while making a non-destructive test, and does not have to have an autographic or other recording of the whole curve. Applied to the set of irons studied by the A.S.T.M., the loads at 0.15 and at 0.20-in. deflection of the 1.20 by 18-in. round bar shows a well defined relationship with graphite content. [See table on page 704.]



Other Functions of Graphite — Some of the more useful functions of the graphite are difficult to evaluate. Due to the brittleness of the chip and the lubricating properties of the graphite, gray iron is the easiest ferrous material to machine at any given hardness level. Graphite also is responsible for its freedom from galling when run on itself and on many other metals. Gray iron is therefore the only material that has been successfully used for brake shoe or brake drum linings. The graphite flakes also act as cushions against thermal shock and thus prevent crazing.

Another credit to gray iron is its almost complete insensibility to the notch effect. [It's already adequately notched!] Endurance specimens with filleted grooves which reduce the resistance of steel by 74% had no effect on soft iron.

The high damping capacity of gray iron is entirely due to the cushioning effect of the graphite.

Professor Howe said: "Graphite itself is a source of weakness and brittleness. Its presence is sought rather for process than for product purposes." This was said before the automobile had taught the value of gray iron in resistance to wear and galling, and before autogenous welding had proved that strength and rigidity alone could not overcome vibration in heavy, high speed machinery. I believe that, were he alive today, he would be the first to recognize the value of the engineering material I have described as Steel plus Graphite.

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AMPCO-TRODE

Heavy-duty bearing surfaces — in heavy machinery, ordnance, pumps and valves, etc. — last several times as long, when overlaid with Ampco Metal — the superior alloy of the aluminum bronze class.

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Leveling pistons for giant shovel overlaid with Ampco-Trode

This 2,800,000 lb. stripper, designed and built by Bucyrus-Erie Company, has an automatic leveling mechanism operated by hydraulic jacks. At one end of each jack piston, 16 sq. ft. of steel bearing surface is overlaid with Ampco-Trode Grade 18.

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The thumbscrews are so positioned on the conveyor belt by the operator that only the tip is heated. Only a ten-second treatment is required.

JUST the 1/8-inch tip of these small thumbscrews—part of a hose-clamp assembly for airplanes, tanks, and other war equipment—must be annealed. The rest of the screw must remain hardened right out to the end of the threads.

By conventional heating methods it was difficult to confine the heat properly—and cost was excessive.

Now, with a single G-E electronic heater, the Wittek Manufacturing Company, Chicago, Ill., (a leading manufacturer of aviation hose clamps) anneals *100,000 thumbscrews a day—at one-half the former cost—and with absolute uniformity of results!*

A simple conveyor belt automatically positions the thumbscrews so that *only the tip* passes through the coil of the heater. Thus, the heat is concentrated on this one small section, and the rest of the screw is not affected.

That is a typical example of precision heat-treating being done today by inductive heating with G-E electronic heaters. With this versatile process you can heat practically any metal. You can anneal, harden, braze, or solder in a very short time and with great accuracy—the heated zone can be controlled to within a small fraction of an inch. It will pay you to investigate the many ways G-E electronic heaters can improve both your present and your future operations. Simply contact the nearest G-E office, or write to General Electric Company, Schenectady 5, New York.

5 IN A SERIES OF CASE STUDIES *on the accomplishments of G-E electronic heaters, a new and powerful tool that is speeding American war production. Like most new tools, it can easily be misapplied. The recommendations of G-E Industrial Heating Specialists are based on the experience gained with more than 200 installations of electronic heaters, plus a quarter century of experience in the development, manufacture, and application of electric heating equipment of all types.*

GENERAL ELECTRIC

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ELECTRONIC HEATERS

Every week 192,000, G-E employees purchase more than a million dollars' worth of War Bonds.

Magnesium

(Continued from page 680)

which consists of a framework carrying about a hundred canvas-covered leaves. The milk is drawn through these leaves, caking on them to a depth of around 1½ in. Then a 100-ton traveling crane neatly lifts out the unit and lowers it into another compartment where air blows the cake off the screens and the white lumps go by conveyor to what are called the neutralizing units.

These are rubber-lined, steel tanks and in them the magnesium hydrate is treated with hydrochloric acid and becomes magnesium chloride — which is the same raw material as used at Midland. This is treated and dried and becomes the feed for the electrolytic cells which extract the pure magnesium. It is in this fashion that a barrel of sea water becomes a third of a pound of magnesium.

First ladle of magnesium w poured January 21, 1941. The o unlooked-for complication ca through a small contamination boron in the cell feed. It caus an unfamiliar sludge to form the bottom of the cell, which h to be dipped out by hand a which caused a drop in metal p duction to one-third of capaci

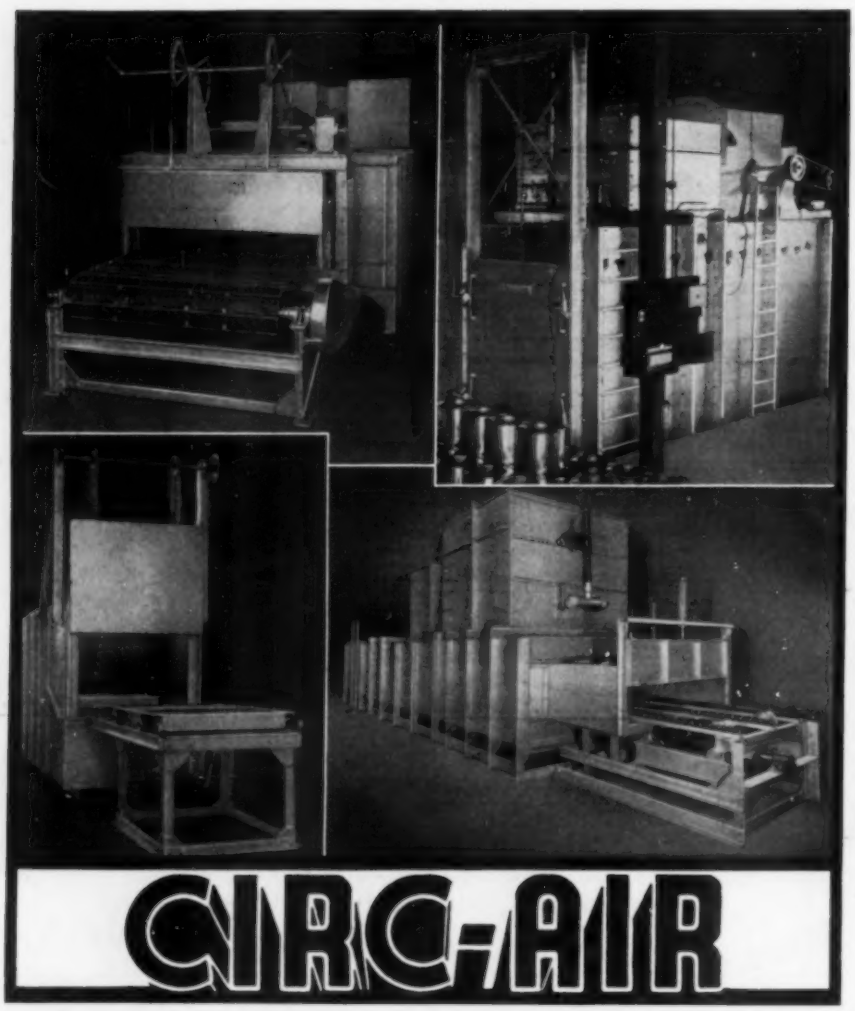
The remedy turned out to quite simple. It was found th by adding a little extra lime in t hydrating process, the boron stay in solution and went off with t waste water.....

Recent history of magnesium largely one of a belated rush t production and even more produ tion.* In May 1940 the Preside recommended a stupendous p gram, including many thousan more airplanes than most peo believed it would be possible construct. Nobody knew how mu magnesium would be required. assistant chief of the Air Co wrote that 1.2% of the engine a 1.0% of the airframe would magnesium. This works out to lb. per airplane, or 10,000,000 for the 125,000 planes of 19 (War Production Board in Feb ary 1943 showed an annual requi ment of 142,724,000 lb. for aircr —1000 lb. per plane—pl 28,000,000 lb. for alloying w aluminum.)

Dow made one expansion af another. At the same time, Government requested us to ma available its know-how to responsible company financed the Defense Plant Corp. We agre Two groups took advantage of opportunity, one at Painesvi Ohio (rated capacity of 36,000, lb.) and the other at Austin, Tex with a rated capacity of 24,000, Eight other concerns contrac with Defense Plant Corp. to bu and operate plants for the acco of the Government, following ot production techniques.

The facts for 1943 show t the rated annual capacity of all magnesium metal plants in country was 580,000,000 lb. W the Dow group had 44% of t rated capacity, they actually p duced 60% of all the magnesi made. The Government has investment of 80¢ for every po of magnesium produced in 1943 the Dow group, and $1.67 for ev pound produced by the others.

★See *Metal Progress*, March 1942, p 339, for a statement of the 1941 prog and November 1943, page 952, for a on its accomplishment.



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FINE INDUSTRIAL FURNACES SINCE 1917

There's a Circ-Air furnace to exactly meet your heat treating requirements. At upper left is a continuous type for aluminum, 300° F. to 1000° F., 2000 lbs. per hr. Upper right is a batch type for castings and wrought aluminum. Lower left is a small, car type, batch furnace adaptable to several processes and a real "handy-man" in the small plant. Lower right is an automatic pusher type furnace for solution treatment of aluminum. Capacity 500 to 1000 lbs. per hr.

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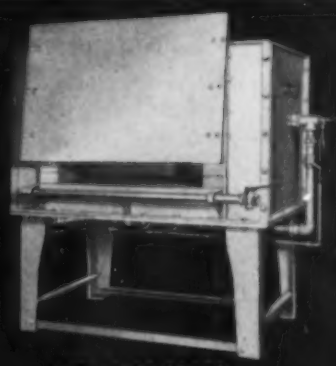
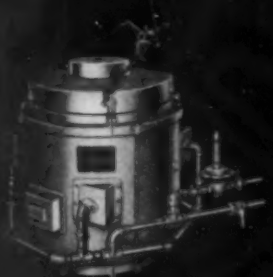
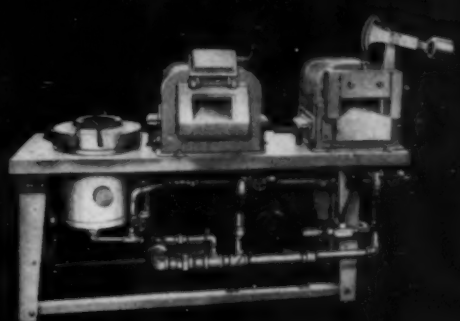


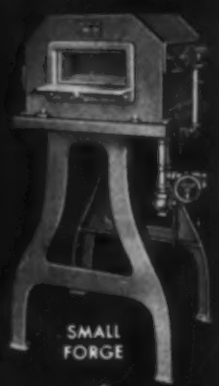
OPEN SLOT FORGE



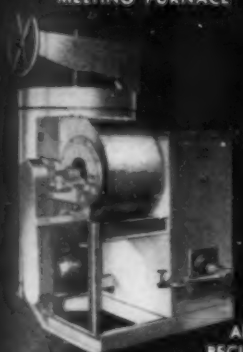
STATIONARY METAL MELTING FURNACE



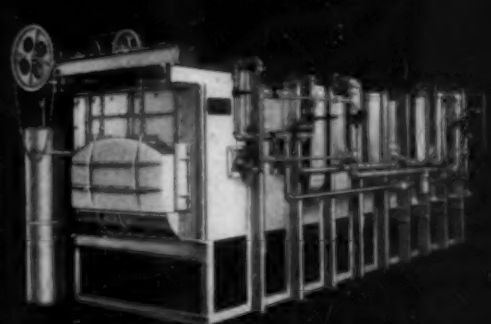
TRIPLE PURPOSE COMBINATION



SMALL FORGE



AIR DRAW RECIRCULATING FURNACE



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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Wall charts and manual sheets by Firth-Sterling Steel Co. make easy the selection of color-branded sintered carbides for cutting tools. Bulletin 391.

Marvel metal cutting saws. Armstrong-Blum Mfg. Co. Bulletin 395.

16-page booklet features 22 short stories of how proper cutting fluids have solved production problems. D. A. Stuart Oil Co. Bulletin 403.

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

New leaflet describes the Doall band filing machine. Continental Machines, Inc. Bulletin 430.

Complete and valuable study "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Lubricoolant, a new type of coolant said to prolong tool life on metals from chrome-molybdenum steel to aluminum alloys, is described in new leaflet issued by the DuBois Co. Bulletin 408.

Complete summary of new Doall tools is presented in new booklet issued by Doall Service Co. Bulletin 432.

Safe-T tongs and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

63-page pocket booklet shows useful tables of weights and measures used in the metal industry. Mesta Machine Co. Bulletin 441.

Practical data sheet describes cutting and grinding compound. Diversey Corp. Bulletin 447.

FERROUS METALS

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 24

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 770, 772, 775, 778, 77 782, 786, 788, 790, 792, 794, 795, 798 and 80

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — April, 194

Send me the Literature I have indicated below.

Name ..... **Title** .....

Company ..... **Address** .....

(Students—please write direct to manufacturers).

Check or circle the numbers referring to literature described on these 15 pages.

1	41	78	106	143	171	199	250	316	347	375	407	433	455
2	42	79	107	144	172	200	251	318	350	376	408	434	456
3	43	82	109	146	173	201	252	319	351	377	409	435	457
4	45	83	114	147	174	202	255	320	353	380	410	436	458
5	48	84	115	148	175	203	258	322	354	381	411	437	459
7	51	85	116	149	176	204	271	323	357	383	413	438	460
8	52	86	117	150	177	206	281	324	358	384	414	439	461
10	56	89	118	152	179	207	284	325	359	385	415	440	462
12	57	91	119	154	180	208	288	327	360	387	417	441	463
15	59	93	122	155	182	210	291	328	361	388	419	443	464
20	60	94	123	156	183	212	292	329	362	390	420	445	465
21	62	95	128	158	184	213	296	330	363	391	421	446	466
24	65	96	132	160	185	215	297	331	364	394	422	447	467
25	66	97	134	161	186	232	301	333	365	395	423	448	468
26	67	98	135	162	189	234	305	335	366	397	424	449	469
30	70	99	137	163	190	240	307	337	367	398	425	450	470
31	71	101	138	164	192	241	312	338	368	399	426	451	471
33	72	102	139	165	193	243	313	339	369	403	428	452	472
35	75	103	141	167	196	245	314	343	372	404	430	453	473
40	76	105	142	170	197	246	315	345	374	406	432	454	474

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PROBLEM: **How to braze an inner cup to the outer shell of an aircraft part . . . in *seconds*?**

ANSWER: **Megatherm High Frequency Heat — with definite control of heat location by means of a simple director coil!**

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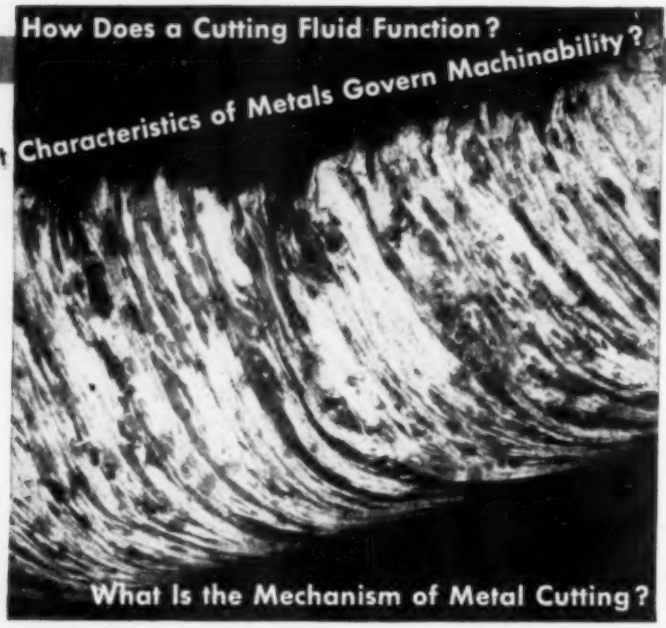
Consider the Lowly Chip..


How Does a Cutting Fluid Function?
What Characteristics of Metals Govern Machinability?
What Is the Mechanism of Metal Cutting?

What Knowledge Its Gnarled Features Hide!

We're moved to poetic expression when we contemplate the great advances in metal-working which become possible as more and more is learned about the formation of a metal chip. Too long the chip has been taken for granted as just something which happens when you cut metal. Scientific investigation is bringing to light data which may greatly alter present day conceptions of tool angles, depth of cut, tool speeds, cutting fluids and other factors which are a part of metal cutting.

Through study of the metal chip come further answers to three fundamental questions: "What is the mechanism of metal cutting?" "What characteristics of metals govern machinability?" and "How does a cutting fluid function?"

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Chemical analyses, shapes and sizes of Joslyn stainless steel products. Joslyn Mfg. and Supply Co. Bulletin 297.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock. H. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

Engineering and comparative information on porcelain enameling iron is presented in new illustrated booklet by American Rolling Mill Co. Bulletin 376.

New booklet gives full information on N-A-X high tensile and N-A-9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

Technical data booklet on Mo-Man steels is offered by Cleveland Twist Drill Co. Bulletin 435.

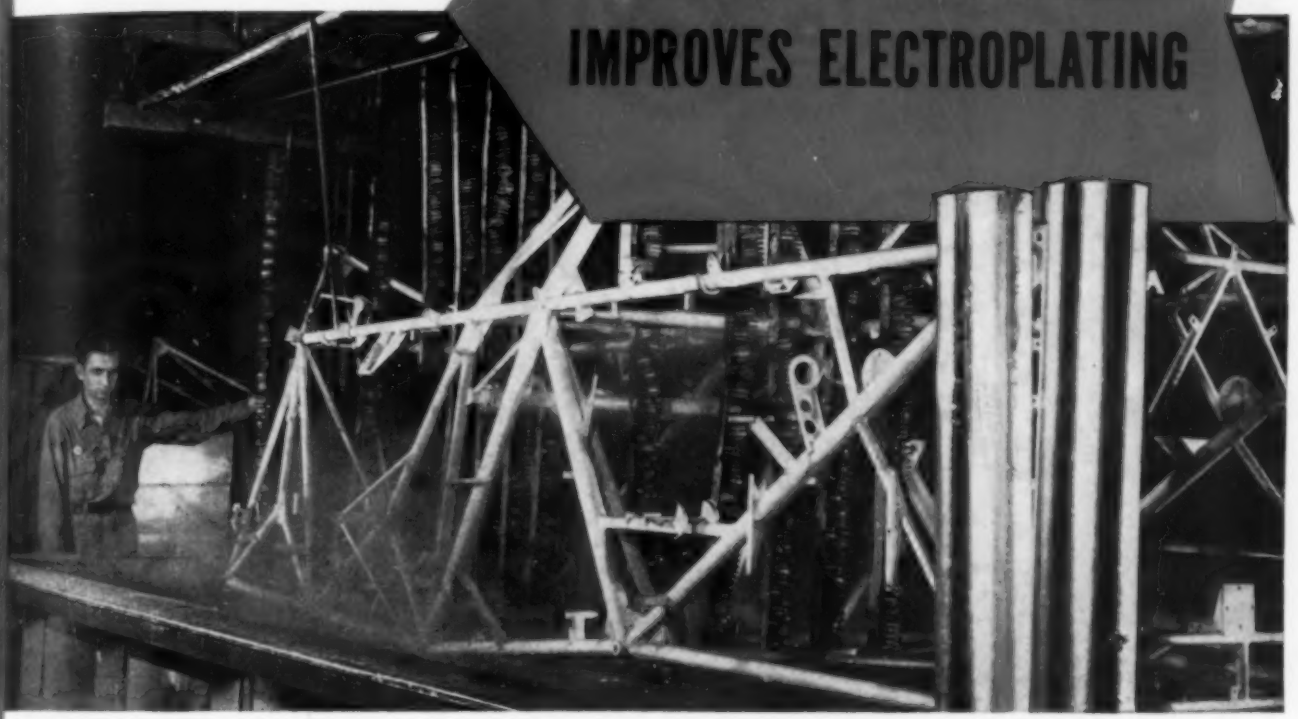
Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 772, 775, 778, 779, 782, 786, 788, 790, 792, 794, 795, 798 and 800

Prosolv *B*

offers outstanding advantages

NEW TURCO CLEANER IMPROVES ELECTROPLATING



Equally effective in still tank and electro-cleaning

So positive are the advantages of Turco Prosolv *B* that prominent electroplaters have switched to this new cleaner immediately following tests *although they had considered satisfactory the materials they had been using.*

Turco Prosolv *B* insures the chemical and physical cleanliness that is essential to 100% bonding to steel of zinc, cadmium, chromium and other plate. It removes every trace of oil, grease, smut, paint and rust preventive compound. It contains no soap; leaves no deposit. Rinsing is complete, even though parts may have dried.

A highly concentrated product, Turco Prosolv *B* is 100% active. Every particle works; there is no waste.

As this new cleaner is effective in both still tank and electro cleaning, it simplifies stocking and plant procedure where both processes are employed.

Try Turco Prosolv *B* for stripping tin deposits formed during certain electro-pickling processes. A standard cleaning tank may be used for this.

Call the Turco Field Service Man for details on this specially formulated electro and still tank cleaning material which is doing such a notable job the nation over. Write today.

Follow Prosolv *B* with Turco Descaler This second step in preparing steel for plating is as necessary to a perfect job as the primary cleaning operation in Prosolv *B*. Any rust, mill, welding or heat-treat scale will prevent bonding of plate. Turco Descaler removes these without attacking the base metal. Thus the combination of Turco Prosolv *B* and Descaler insures quality plating at low cost. Let us furnish full details.

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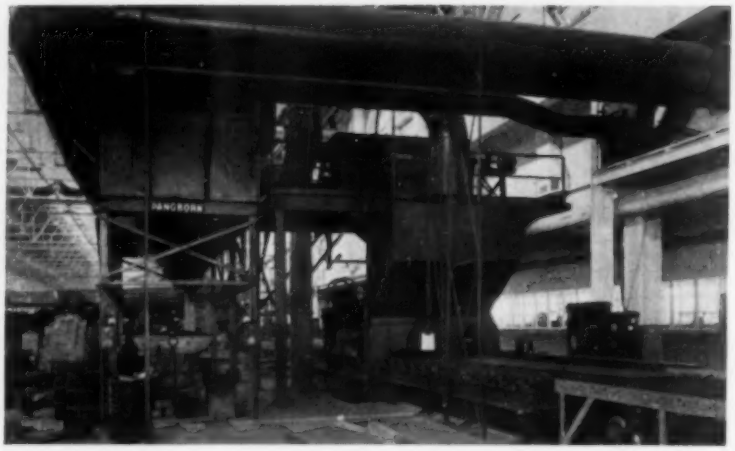

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SPECIAL Pangborn Air and ROTOBLAST* Cleaning Machines are those that have been CUSTOM DESIGNED TO FIT INDIVIDUAL BLAST CLEANING REQUIREMENTS.

They are automatic installations *exactly* built to clean unusual sizes and shapes of gray iron, steel and malleable castings, forgings, heat-treated parts, armor plate, etc.

Designed by Pangborn engineers who have 40 years blast cleaning experience behind them, and built by picked workmen, these SPECIAL Blast Machines set a new high record for quality and economical production in the Metal Industry today.

Forty-two concerns have from 2 to 23 installations each in their plants. These REPEAT orders for "SPECIALS" indicate clearly the satisfactory performance of this great army of Pangborn machines.

SPECIAL equipment for your operations can be worked out to show a very substantial increase in production schedules at lowered cost — either for NOW or for POST-WAR requirements. Write for detailed information.

For excellence in production

*Trade mark of Pangborn Corporation for airless blast cleaning.

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WORLD'S LARGEST MANUFACTURER OF DUST COLLECTING AND BLAST CLEANING EQUIPMENT

PANGBORN CORPORATION · HAGERSTOWN, MD.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

64-page booklet describes the welding of stainless steels. Allegheny Ludlum Steel Corp. Bulletin 384.

84-page tool and die steel handbook just issued by Ziv Steel & Wire Co. is a helpful guide to selection, treatment and use of these important steels. Bulletin 440.

32-page booklet which pictorially and textually amounts to a scientific treatise on two carbon steels—Speed Case and Speed Treat—has been issued by W. J. Holliday & Co. Bulletin 450.

Fitzsimons Co. issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

NON-FERROUS METALS

This "Aluminum Imagineering Notebook" presents 12 important economic advantages of aluminum and illustrates numerous examples of things which have been imagineered into aluminum actualities. Aluminum Co. of America. Bulletin 472.

80-page pipe and tube bending handbook has been issued by Copper & Brass Research Assn. Bulletin 399.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Copper Alloys. American Brass Co. Bulletin 45.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 770, 775, 778, 779, 782, 786, 788, 790, 792, 794, 795, 798 and 806.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

20-page book shows each step in production of brass and aluminum castings by Manufacturers Brass Foundry Co. Bulletin 414.

"Designing with Magnesium" is title of new book offered by American Magnesium Corp. Bulletin 433.

WELDING

40-page catalog reviews the progress and many applications of low temperature welding. Eutectic Welding Alloys Co. Bulletin 471.

16-page booklet outlines the many advantages of the P. & H. control system for production welding. Harnischfeger Corp. Bulletin 474.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Welding and brazing of aluminum, new data book issued by Aluminum Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Shield Arc electrodes. McKay Co. Bulletin 67.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 251.

32-page catalog describes line of welding equipment offered by Victor Equipment Co. Bulletin 245.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin 251.

New 500 lb. capacity welding positioner for light welding jobs is described by Ransome Machinery Co. Bulletin 313.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 768, 770, 772, 778, 779, 782, 786, 788, 790, 792, 794, 795, 798 and 806.

this girl is identifying STEEL *positively*

With only a few hours training in the operation of the Identometer, this girl can, through the use of known samples of most rolled or forged ferrous alloys, determine if unknown pieces are: (1) of the same or different chemical composition, if the physical structure is the same; (2) of the same heat or different heat treatments, if the chemical composition is the same.

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The instrument is the Identometer. Its principle: thermo-electricity. It's portable, accurate, and fast. For a full "how it works" description, send now for Bulletin 111. DRAVO CORPORATION, *National Department*, 300 PENN AVENUE, PITTSBURGH 22, PA.

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

New line of welding positioners with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

Arc welding inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

Many uses and advantages of Colmonoy hard facing alloys and overlay metals are illustrated in new 8-page folder issued by Wall-Colmonoy Corp. Bulletin 415.

New Phos-Copper booklet explains ways to braze, design and applications. Westinghouse. Bulletin 455.

TESTING & INSPECTION

Latest technical literature on x-ray and radium protection, together with lead products catalog, has been issued by Bar-Ray Products, Inc. Bulletin 463.

Magnetic analysis equipment for inspecting steel bars and steel tubes is described in this booklet by Magnetic Analysis Corp. Bulletin 464.

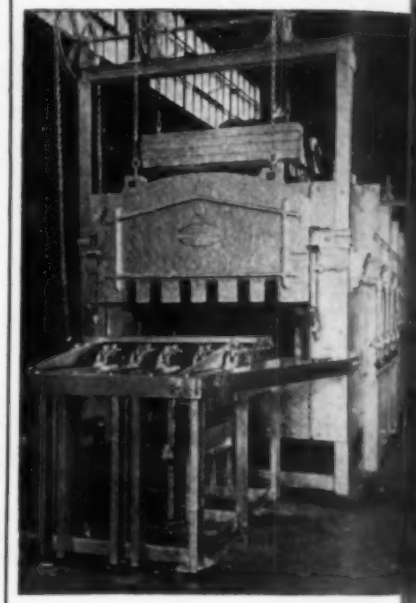
The Bristol-Rockwell dilatometer and its use is described in this leaflet by The Bristol Co. Bulletin 465.

250 KV industrial x-ray units — jib crane, mobile and dolly — are described in this new booklet. Picker X-Ray Corp. Bulletin 468.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 779, 782, 786, 788, 790, 792, 794, 795, 798 and 806.

BELLEVUE *Job-Designed* FURNACES



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WHAT'S NEW
MANUFACTURERS' LITERATURE

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and booklet discussing this equipment offered by E. H. Sargent & Co. Bulletin 338.

SR-4 strain gage and illustrations its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Electric heaters and controls for industrial and laboratory. American Instrument Co. Bulletin 75.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Portable Brinell hardness tester and folding Brinell microscope. Andrew Engineering. Bulletin 85.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

Stresscoat, a method of analyzing distribution, direction and value of local strains. Magnaflux Corp. Bulletin 301.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature listed on Pages 768, 770, 772, 775, 778, 782, 786, 788, 790, 792, 794, 795, 798 and 806.

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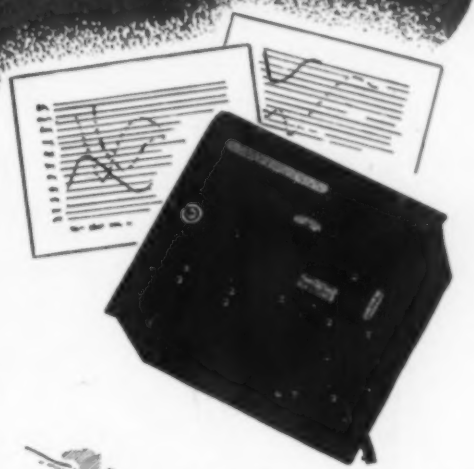

Time saving procedures, using Coleman Spectrophotometers* are shown in the new and revised "Curves and References". Molybdenum, phosphorus and manganese references are also given.

One user reports "... *copper, nickel and molybdenum determinations are done in 20 minutes using the UNIVERSAL, as compared to 90 min. formerly required.*"

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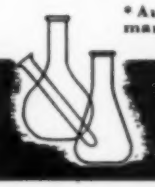
Turning one knob permits selection of any color light band required . . . Coleman Universal Spectrophotometer, at $340.00 — replaces visual and filter colorimeters.



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INDIRECT ARC ROCKING FURNACE. *Can produce up to 1000 lbs. per hour of such alloys as Monel metal, heat-resisting stainless steel, nickel cast iron, etc.*

The Duriron Company, Inc. has . . .

- **Many comparatively small melting units.**
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These provide flexibility to produce specialty castings of many analyses to precise and difficult specifications.

DIRECT ARC FURNACE. *Regularly producing 3500 lb. heats of specialty carbon steels and heat-resisting stainless steels.*

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STAINLESS STEELS, *Corrosion-Resisting:*
Durimet T
Durimet 20
18-8S
18-8SMo

STAINLESS IRONS:
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18% Cr
28% Cr

STAINLESS STEELS, *Heat-Resisting:*
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35% Ni, 15% Cr

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HIGH FREQUENCY INDUCTION FURNACE, *the accurate tool for making low carbon stainless steel. Durco operates a battery of four of these units, ranging from 150 lbs. to 2400 lbs. melting capacity.*

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BUT MORE IMPORTANT is the organization that has successfully produced these alloys and has the "know how" to use these splendid facilities; an organization that gives the highest ratio of supervision per pound of castings produced.

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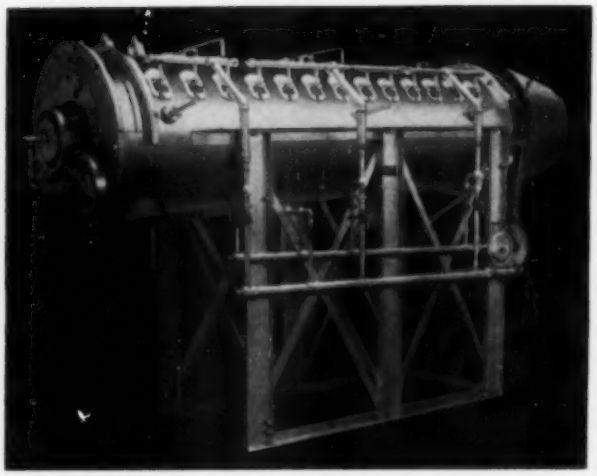

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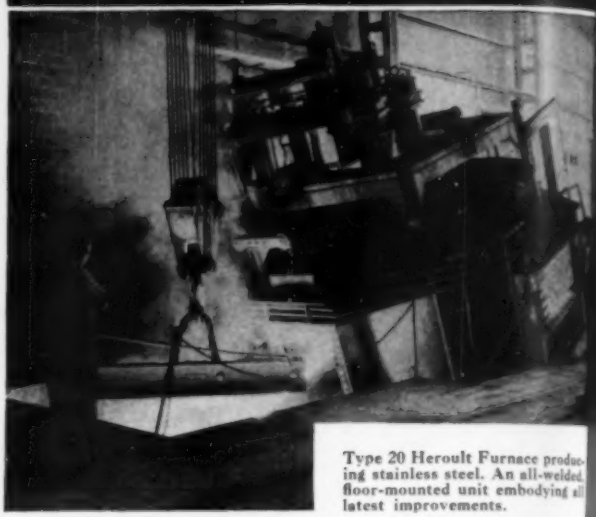

Type 20 Heroult Furnace producing stainless steel. An all-welded, floor-mounted unit embodying all latest improvements.

PARTICULARLY designed and equipped for high-quality melting and refining of ferrous materials by either basic or acid process—including alloy, tool and forging steels, iron and steel castings. Any capacity from ½ ton to 100 tons; removable roof, chute, machine or hand charging.

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United States Steel Export Company, New York

UNITED STATES STEEL

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

Two new folders describe Searchray 80, new self-contained X-ray unit of North American Philips Co. Bulletin 377.

High intensity industrial illuminator is illustrated and described in new leaflet by Kelley-Koett Mfg. Co. Bulletin 406.

30th Anniversary Catalog shows the special metallurgical equipment offered by Claud S. Gordon Co. Bulletin 410.

Laboratory and industrial pH meters are described and explained in leaflet issued by Beckman Instruments Division. Bulletin 422.

8-page illustrated leaflet describes line of industrial instruments offered by the Brush Development Co. Bulletin 428.

"Spectrographer's News Letter" is title of interesting new publication by Harry W. Dietert Co. Bulletin 451.

TEMPERATURE CONTROL

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

New leaflet describes valve operator of industrial operation of valves, dampers and other control devices. Automatic Temperature Control Co. Bulletin 381.

Industrial thermocouples. Ark... S. Richards Co. Bulletin 93.

New Pyrometer Accessory M... ual gives engineering data on sel... tion and installation of therm... couples. The Bristol Co. Bulle... 421.

16-page booklet describes and ... lustrates Wheelco Instrument C... line of measuring and control ... struments. Bulletin 425.

HEATING • HEAT TREA... MENT

Equipment for determining ... quantity of sodium cyanide in mo... cyanide mixtures used in heat tr... ment is described in new bulletin ... the Kocour Co. Bulletin 394.

Design features of gas-fired ... furnaces are illustrated in this 8-p... leaflet. Surface Combustion. ... letin 460.

"Isothermal Quench Baths App... to Commercial Practice" is the ... of this 12-page paper, a pract... and useful discussion of S curve... heat treatment. Ajax Electric ... Inc. Bulletin 461.

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Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 779, 786, 788, 790, 792, 794, 795, 798 and

Save 75% of your time and material cost with the Nelson Model "H" Stud Welder!

Wide-awake industries are *doing it*, too! The great saving in time, material and labor effected by the Nelson Stud welding process is only one of its many advantages.

The welding process is entirely automatic—your workers are able to weld 500 to 1000 studs in one day. The results obtained by the Nelson Model "H" Stud Welder are uniformly satisfactory—complete fusion of the stud to the steel plate is obtained by accurate control of the arc timing, automatic action of the welding gun, the use of a special flux-filled stud and complete shielding of the arc by the use of a porcelain ferrule.

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Fiberglas, sprayed-on asbestos, or similar materials, can in this way be easily applied.

1/2" DIA. SHOULDER STUD
with 3/8" dia. threaded extension

Used for securing wireways, control boxes and fixtures. Effects a uniform spacing from bulkhead to fixture.

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For securing pipehangers, gun mounts, manhole covers, etc.

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HARDNESS TESTER

FOR "ROCKWELL" TESTING

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

32-page booklet describes 16 interesting industrial uses of high frequency electrical induction. Ohio Crankshaft Co. Bulletin 459.

Quenching oil coolers in heat treating practices are described in this leaflet by the Sims Co. Bulletin 462.

New catalog No. 406 describes Rockwell valves for control of air, gas and liquids. W. S. Rockwell Co. Bulletin 466.

Neutral baths for heat treatment and details of their use are described in this booklet by the A. F. Holden Co. Bulletin 469.

24-page technical data and operating manual covering the Deepfreeze low temperature industrial chilling machines has been issued by Deepfreeze Div., Motor Products Corp. Bulletin 398.

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin 99.

Induction heating. Induction Heating Corp. Bulletin 103.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin 102.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin 105.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 788, 790, 792, 794, 795, 798 and 806.

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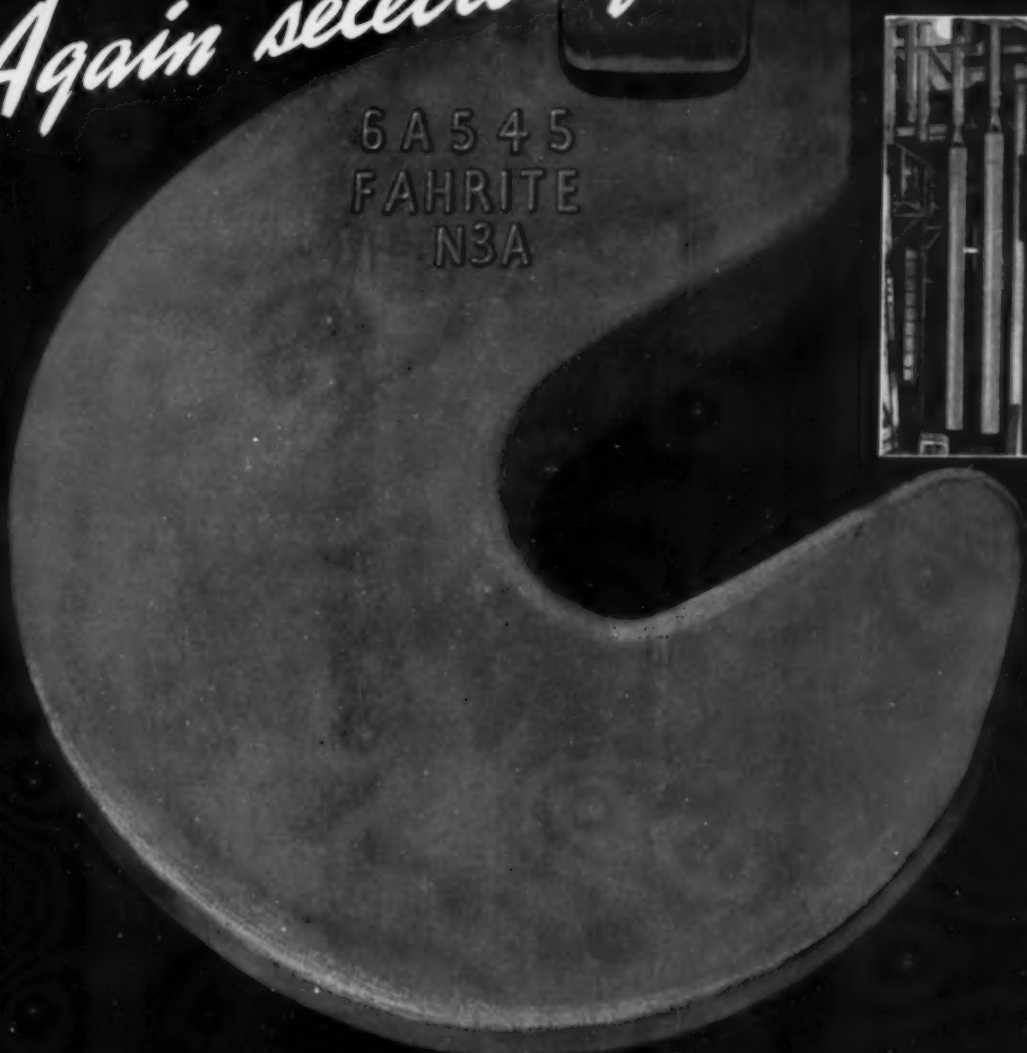
FAHRITE

HEAT AND CORROSION RESISTING ALLOYS

Again selected for a big job



The uninterrupted flow of gun barrels through heat treating furnaces has built up America's fire-power to tremendous strength. FAHRITE castings—such as the big hook shown above—have supported enormous quantities of heavy barrels through the furnaces.

For *any* purpose where permanent strength at elevated temperatures is necessary, you can depend on tailor-made castings of FAHRITE, the alloy whose high nickel and chromium content withstands heat at which ordinary steel would oxidize.

ARMY E NAVY

THE OHIO STEEL FOUNDRY COMPANY

LIMA AND SPRINGFIELD, OHIO

ENGINEERS • FOUNDERS • MACHINISTS

FREE ENTERPRISE IS THE ONLY WAY TO CONSTANTLY HIGHER AMERICAN LIVING STANDARDS

Contour Sawing
7 Models
Band Filer
Super Surface Grinders
Grinding Wheels
Magnetic Chucks and Selectron
Cutting Oils and Soluble Oils
Dust Collectors and Coolant Systems
Speedmaster
Variable Speed Pulleys
Band Saws
Band Files
Inspection Laboratory
GAGE BLOCKS with Instruments
POWDER METALLURGY
Metal Powders
and Equipment
INDUSTRY'S NEW SET OF TOOLS
DoALL
Write for literature, mentioning products in which you are interested.
THE DoALL COMPANY, Des Plaines, Ill.
Sales & Service Offices: Baltimore, Boston, Chicago, Cleveland, Denver, Detroit, Erie, Houston, Indianapolis, Los Angeles, Milwaukee, Minneapolis, New Orleans, New York, Orlando, Philadelphia, Pittsburgh, Portland, Rochester, Rockford, St. Louis, Salt Lake City, San Francisco, Seattle, Spokane, Toledo, Tulsa, West Hartford.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Van Norman induction heating units. Van Norman Machine Tool Co. Bulletin 144.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin 138.

Controlled atmosphere furnace. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

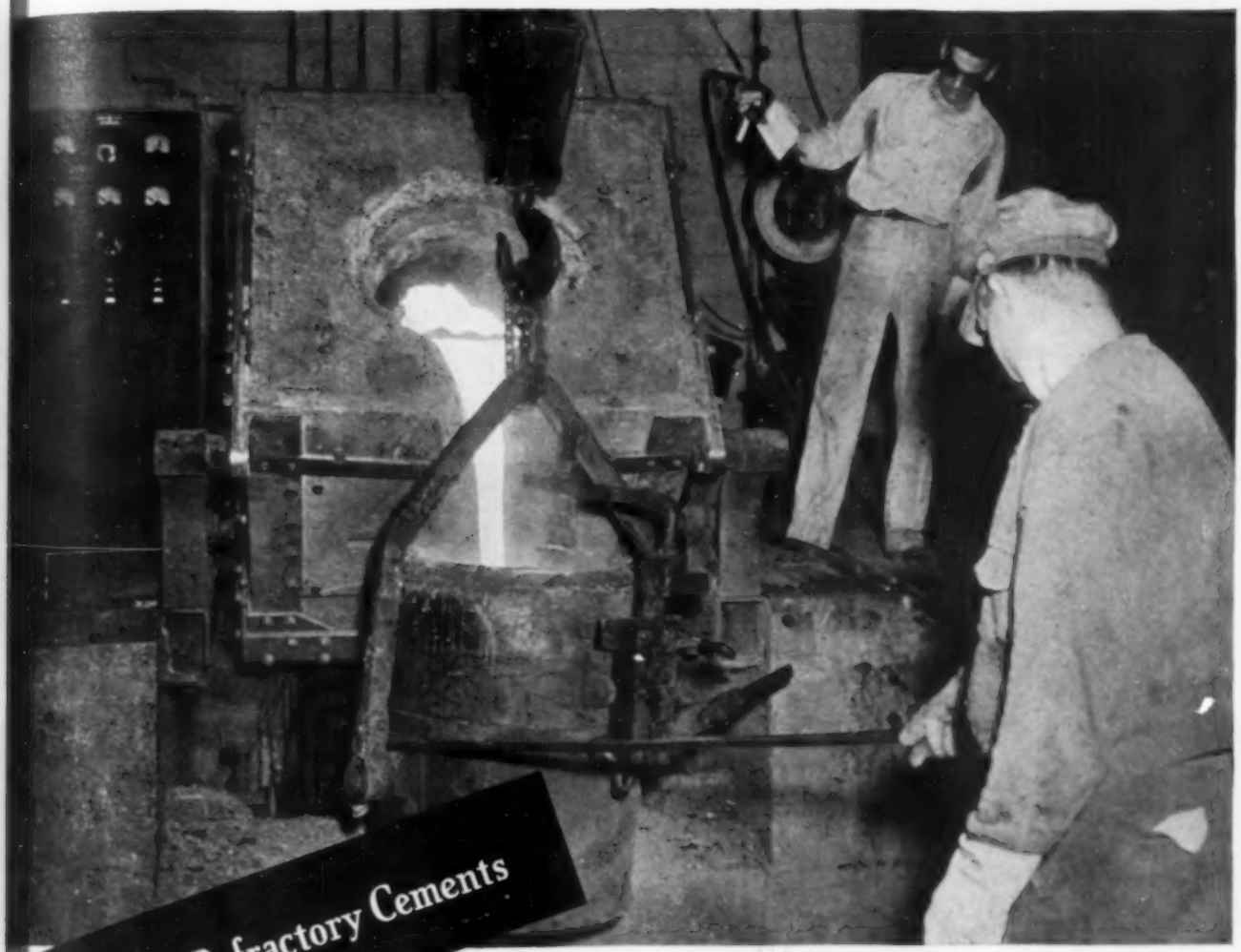
New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin 155.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 786, 790, 792, 794, 795, 798 and 806.



Norton Refractory Cements are finding wide and successful application in the melting of non-ferrous metals. Among these cements are:

RC 1131 — a CRYSTOLON (silicon carbide) cement of high refractoriness for ramming into oil or gas fired reverberatory and pit furnaces melting aluminum. Also recommended for melting copper and zinc.

RM 1169 — a fused magnesia cement, ideal for lining Ajax-Northrup high frequency furnaces melting nickel-chromium alloys.

RA 889 — an ALUNDUM (electrically fused alumina) cement recommended for lining burner tunnels in gas or oil fired billet heating, heat treating and annealing furnaces.

RM 1140 — a fused magnesia cement for rammed linings in Ajax-Wyatt low frequency vertical ring induction furnaces melting high copper alloys (more than 85% copper), copper-nickel alloys, nickel silver, and cadmium bronzes.

NORTON COMPANY
Worcester 6 Massachusetts

R-876

Norton Longer Lasting Refractories

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

Protective combusted atmospheres in Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin 160.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amaler Morton Co. in Bulletin 361.

Illustrated bulletin on stress-relieving, car-type furnaces. Radiant Combustion. Bulletin 375.

Furnaces for heat treating tools dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

82-page ... log describes in detail General Electric heat treat furnaces. Bulletin 380.

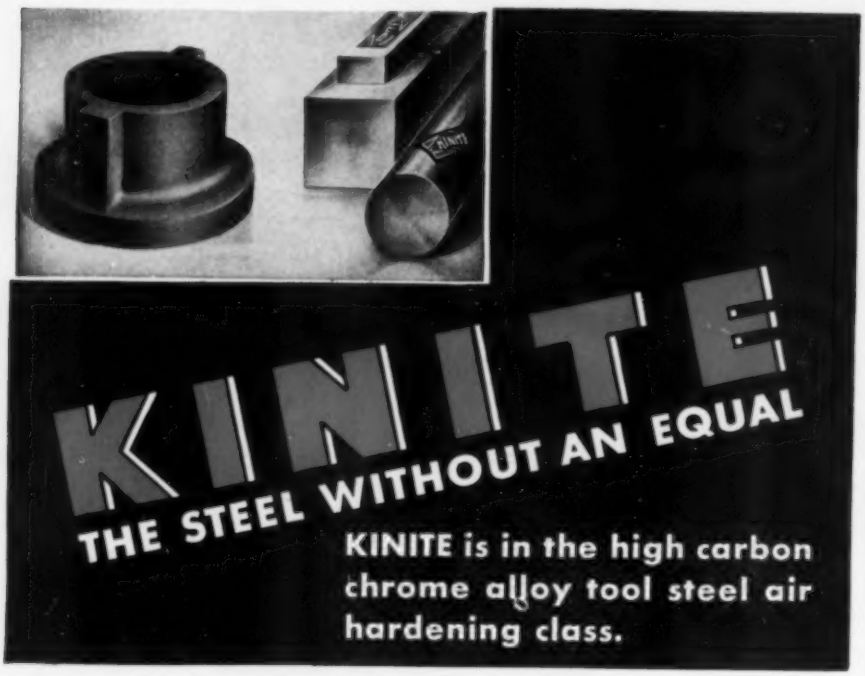
Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

War Production Data — 30 pages of useful information on metal working, heat treating and other metal producing operations just issued by E. F. Houghton & Co. Bulletin 387.

Laboratory and tool room furnaces Mahr Mfg. Co. in new Bulletin 327.

Heat Treating Topics" is title of new bulletin of special interest to heat treaters, issued by Rex & Erb. Bulletin 424.

Vapocarb-Hump method for heat treatment of steel is the title of a newly-revised catalog issued by Leeds & Northrup. Bulletin 453.



An analysis all of its own . . . .
Its characteristics:

1. Increases production.
2. Reduces grinding and retooling time.
3. Resists wear and abrasion.
4. Excellent machinability.
5. Minimum distortion.
6. Fine heat treatability.
7. Immune to cracking during heat treatment.
8. In bar stock or castings.

KINITE alloy air hardening steel offers an unusual combination of features never before found in a steel of this type.

Pamphlets on request.

EST. BOKER 1837

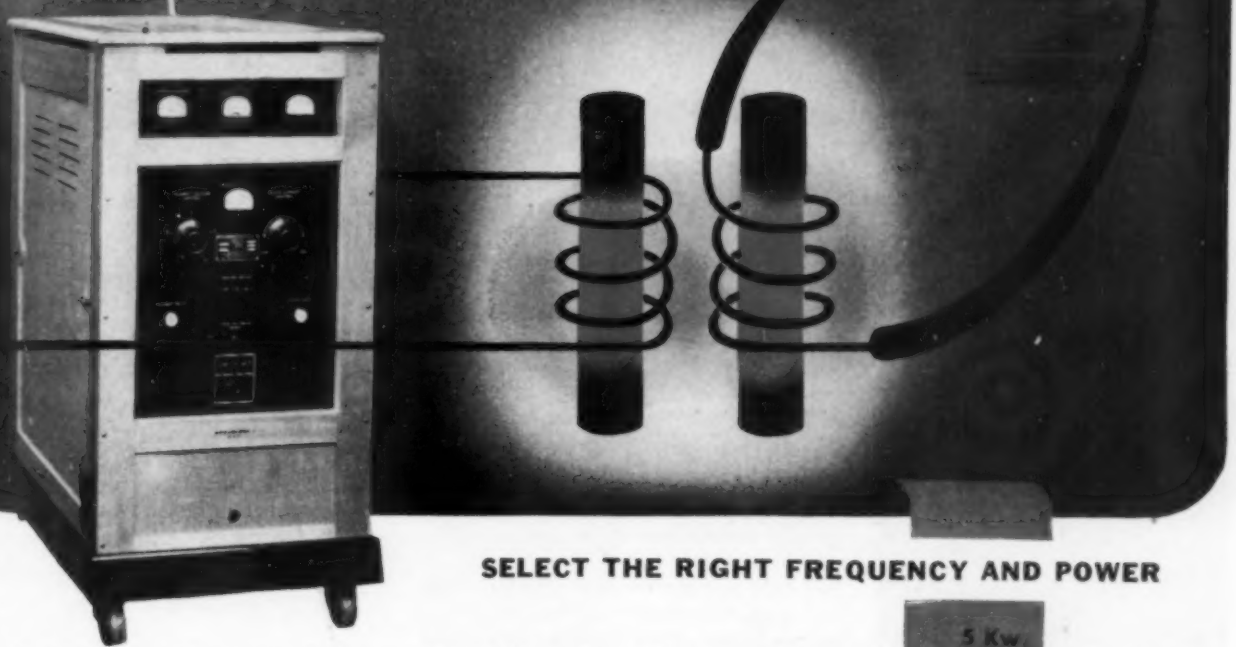
H. BOKER & CO., Inc.
101 DUANE ST. ● NEW YORK

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 786, 788, 792, 794, 795, 798 and 800.

WHY USE A COSTLY "POWERHOUSE"

for hf heating jobs that a more economical unit of PROPER FREQUENCY can do?



SELECT THE RIGHT FREQUENCY AND POWER

Don't tie up a big, expensive heater that delivers more than enough power at the wrong frequency . . . when a unit at a more suitable frequency would do the job just as well, with greater economy and convenience.

There is a unit of correct frequency and power for every heating operation. The cost of a h f heater and the amount of power it should consume are factors which depend on your specific applications.

Let us demonstrate how you can save by fitting the unit of proper frequency and power to the size of the parts being treated. This will release your "powerhouse" or misfit machine for work more suited to its capacity. Many users have proved that one of our installations can pay for itself many times over in the first year.

5 Kw
7½ Kw
10 Kw
12½ Kw
15 Kw
18 Kw
25 Kw
40 Kw
100 Kw

Frequency range up to 300 Mc

Write for money-saving information today

Scientific Electric

DIVISION OF "S" CORRUGATED QUENCHED GAP COMPANY
119 Monroe Street Garfield, New Jersey

AMERICAN INDUSTRY SAVES

$750,000,000

per year by using

KENNAMETAL

PRODUCTS AND ENGINEERING

KENNAMETAL PRODUCTS

CUTTING TOOLS

Kennametal-tipped single-point tools are used in America's leading machine shops for turning, facing, and boring steel up to 550 Brinell hardness, cast iron, and the softer metals.

MILLING CUTTERS

Kennametal-tipped cutters have revolutionized milling practices by making possible the milling of all metals, including the toughest steels, at almost incredible speed.

WEAR RESISTING PARTS

Kennametal inserts are used to prolong precision machine performance by protecting the "wear-areas" against effects of friction, corrosion and erosion.

The carefully recorded experience of one of our customers for the year 1942 indicated that actual savings resulting from the use of Kennametal-tipped machining tools totaled $50,000. Projected to a national basis for the same year, American Industry saved approximately $750,000,000 through the use of Kennametal. In 1943, the widely extended application of Kennametal increased these savings correspondingly.

These are dollars-and-cents figures—figures in which industry is normally interested. But as American citizens, we are today even more interested in how the savings will help win the war—man-hours saved and production gained are the vitally important factors. Every faster cutting operation in your shop means faster cutting of the deep, straight paths of destruction that lead to Berlin and Tokyo. Shortening the job means shortening the war. Shortening the war means saving lives.

You can shorten machining time, and cut costs, by using Kennametal-tipped tools. Kennametal, a cemented carbide composition, contains a unique intermetallic compound (tungsten-titanium-carbide) that is unsurpassed, except for the diamond, in hardness. Our district field engineer can tell you how to use it for maximum metal-cutting results. Kennametal Catalog 43-C contains useful information on tool design, use, and maintenance. Write for it.

KENNAMETAL Inc.

156 LLOYD AVE., LATROBE, PA.

KENNAMETAL

SUPERIOR CEMENTED CARBIDES

Trade Mark Reg. U.S. Pat. Off.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Cromox, new protective refractory coating material for prolonging life of firebrick, insulating firebrick, and castable refractories. Federal Refractories Corp. Bulletin 163.

Super Refractories catalog. Carborundum Co. Bulletin 165.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

D-E insulating materials and their application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

Zircon refractories in aluminum open hearth furnaces. Chas. Taylor Sons Co. Bulletin 347.

Steel Plant Cement for hot or cold patching of soaking pits, open hearths, electric furnaces, forging furnaces and reheating furnaces is described in new folder by Electro Refractories & Alloys Corp. Bulletin 407.

695, a highly refractory, strong magnesia plastic for taphole construction and hot repairs. Basic Refractories, Inc. Bulletin 443.

FINISHING • PLATING • CLEANING

Two new data sheets describe pickle bath toners in liquid and powder form. American Chemical Paint Co. Bulletin 467.

Automatic and semi-automatic plating equipment for a variety of processes and products are illustrated in 40-page booklet issued by Frederick B. Stevens, Inc. Bulletin 397.

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

A protective, deep black finish for steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

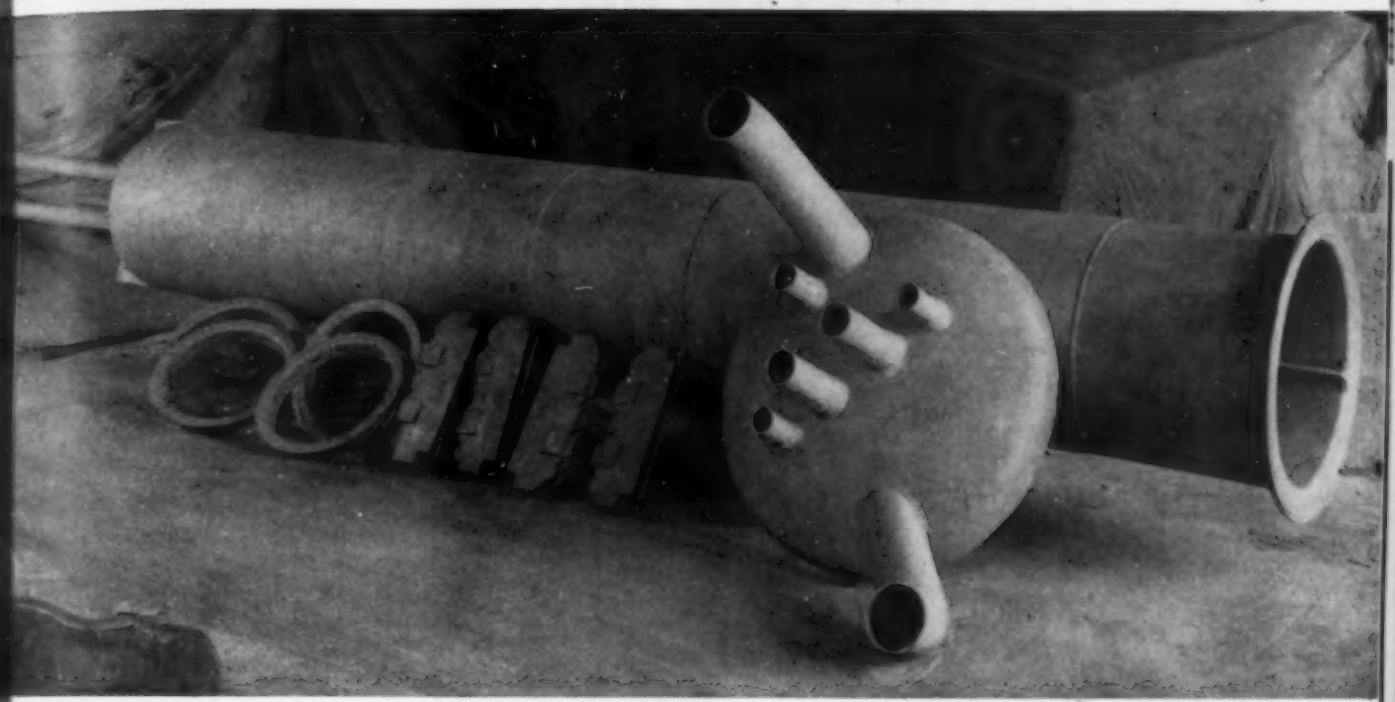
Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

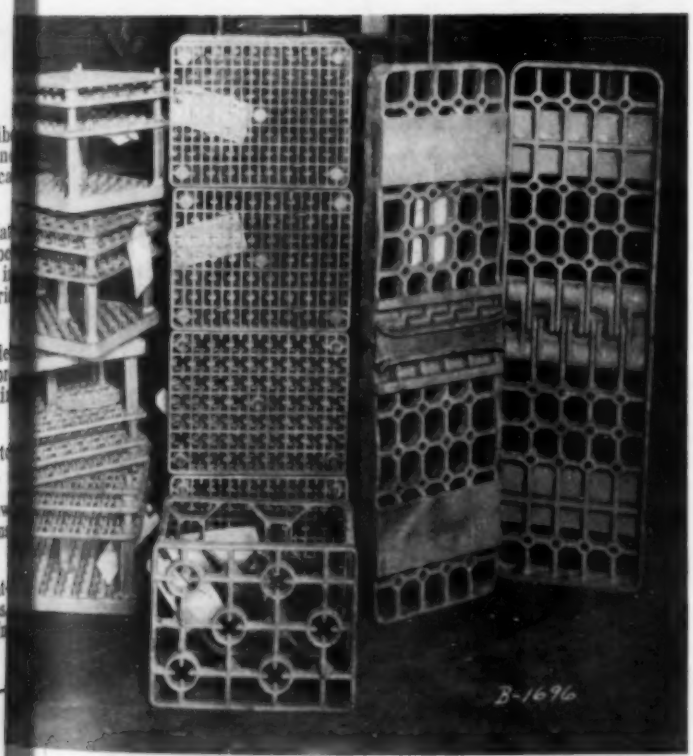
Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 786, 788, 790, 794, 795, 798 and 800

E FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

GA X-ITE GA O'ALLOYS GA X-ITE GA O'ALLOYS



O FURNACE IS BETTER THAN ITS ALLOY PARTS



From the elaborate metallurgical process equipment, to the intricately cast fixtures for heat treating precision gears above, subject to repeated quenching, General Alloys products are selected for tough jobs. Note the hinge tray used in every major automobile plant to double tray life by taking the "flex" out of the alloy and putting it in the hinge.

ALLOY PROGRESS

TWO furnace builders and a ship builder met in New York's "21" Club. After a round evening came an impressive check. "Gimme that," said 1st Fce. Bldr. "We pay 60% Income Tax anyway." "Nuts to that," cracked the second. "We're in the 80% bracket." "Don't fight, boys," said the ship man. "I've *got* to have it. We're on cost plus and it'll make me a six dollar profit."

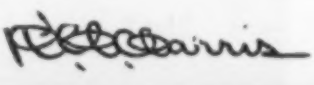
THIS fiction reminds us that the proven peace-time economy of paying General Alloys slightly more for a superior product is greatly magnified when viewed in the light of the tax structure.

IN most plants, alloys are considered as "supplies" and not as "capital" items. Thus in paying 5 to 10¢ more per pound for General Alloys Superior Engineering, metallurgy and foundry practice, most corporations find that Uncle Sam helps out from 5% to 90%.

THIS is a sound investment for "Uncle" too, *for* it is obvious that heat treats equipped with General Alloys products can carry over post-war with better "tooling" to produce economically and put soldiers back to work.

STOPPING to think, you realize that the few top-notch alloy manufacturers were loaded with business well before Pearl Harbor, that by the time the big boom in furnaces and new heat treats came along, the marginal producers, second and third quality manufacturers and steel foundries hopped in to carry the load—God bless 'em. Like the fixed turret tank, and 30 calibre guns on airplanes—they bridged the gap.

GENERAL ALLOYS solicits your inquiries for the highest quality heat resisting alloys, engineered and produced *to your requirements, made to G.A. pre-war standards.*



O'ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

Reduce Rejections
INCREASE Profits
SPEED CASE STEEL

A LOW CARBON OPEN HEARTH PRODUCT..

REDUCED REJECTIONS

- Smooth Finished Parts
- Bending Without Cracking
- Rivets Without Fracture

If you wrote your own specifications for the ideal, all purpose, open hearth carburizing STEEL, it would be . . . SPEED CASE!

"Rejections Eliminated"

After being machined at 235 S.F.P.M., the ends of the long part were bent as illustrated. The small part was machined at 220 S.F.P.M. and after being fitted over the ball part of the large piece, it is rolled over to make a swivel.

Speed Case X1515 replaced SAE 1112 and eliminated rejections entirely.

Estimated Savings per ton of Steel used $41.33.

BUY WAR BONDS

* Write for SPEED CASE PRODUCTION RECORD BOOK. Actual shop records showing savings of 20 to 65%.

Licensor
MONARCH STEEL COMPANY
HAMMOND · INDIANAPOLIS · CHICAGO

Licensee for Eastern States
THE FITZSIMONS COMPANY
YOUNGSTOWN, OHIO
PECKOVER'S LTD. Toronto, Canadian Distributor
MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Pickling. Wm. M. Parkin Co. Bulletin 174.

Detrex metal cleaning machines metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Airless Rotoblast. Pangborn Corp. Bulletin 176.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 177.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Catalog on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

Resilon corrosion-resistant tank linings and applications are described in 8-page leaflet by United States Stoneware Co. Bulletin 291.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

Illustrated booklet describes blast cleaning equipment offered by Ruemelin Mfg. Co. Bulletin 360.

Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

Discussion of anodizing, chromatizing and phosphatizing in illustrated 60-page book has been issued by Turco Products, Inc. Bulletin 243.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials. Oakite Products, Inc. Bulletin 210.

Tumbl-Spray metal washing machine is described in new leaflet issued by American Foundry Equipment Co. Bulletin 413.

Modern polishing wheel weights to give a polishing wheel perfect balance are described by the Manderscheid Co. in Bulletin 417.

Three new booklets have been issued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new alkali steel cleaner. Bulletin 420.

Use Handy Coupon on Page 768 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 786, 788, 790, 792, 795, 798 and 800.

Millions of
POWDERED METAL PARTS
NOW ACCURATELY PRODUCED
ON THE NEW
Kux
POWDERED METAL PRESSES

MODEL 74
WRITE TO DEPT. MP for Catalog or Demonstration

COMPLETELY new patented design features now permit the manufacture of odd shapes of parts with complicated, cored holes, protruding lugs and various sectional thicknesses to micrometer accuracy. The formed pieces are made at speeds of up to 25 pieces a minute with uniform structural density throughout. Completely automatic in operation and applying up to 50 tons total pressure, Model No. 74 will produce parts up to 5" maximum diameter and has a powder cell, or die fill of 5½".

KUX MACHINE COMPANY
1924-44 W. HARRISON, ST. CHICAGO, ILL.

Columbia
TOOL STEEL

MOLY HIGH SPEED—

From an economical standpoint and proven performance, Columbia's MOLITE merits serious consideration for your high speed steel needs.

MOLITE does not require special heat treating equipment.

It pays to use Good Tool Steel.

COLUMBIA TOOL STEEL COMPANY
MAIN OFFICE AND WORKS
500 E. 14TH STREET, CHICAGO HEIGHTS, ILLINOIS

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Metal cleaning solutions for various metals are described in leaflet issued by the DuBois Co. Bulletin 419.

Special data sheets on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

Technical bulletin describes materials developed to meet special-ized processing and cleaning needs. Kelite Products, Inc. Bulletin 438.

New 1944 catalog describes metal cleaning equipment offered by N. Hansohoff, Inc. Bulletin 439.

Several practical data sheets show cleaning methods used on aluminum, brass and steel. Diversey Corp. Bulletin 446.

New 144-page catalog "Chemicals by Glyco" features many tables of useful chemical and physical data. Glyco Products Co., Inc. Bulletin 449.

Technical Service data sheets on pickling solutions. American Chemical Paint Co. Bulletin 456.

ENGINEERING • APPLICATIONS • PARTS

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

New 32-page illustrated booklet contains much data on manganese steel for the railroad industry. American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

54-page booklet, "File 41—Engineering Data Sheets", gives complete facts on Ampco Metal's physical properties and service record. Bulletin 368.

New information sheets on tapered and formed tubes have just been issued by Summerill Tubing Co. Bulletin 369.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Meehanite Castings. Meehanite Research Institute. Bulletin 196.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

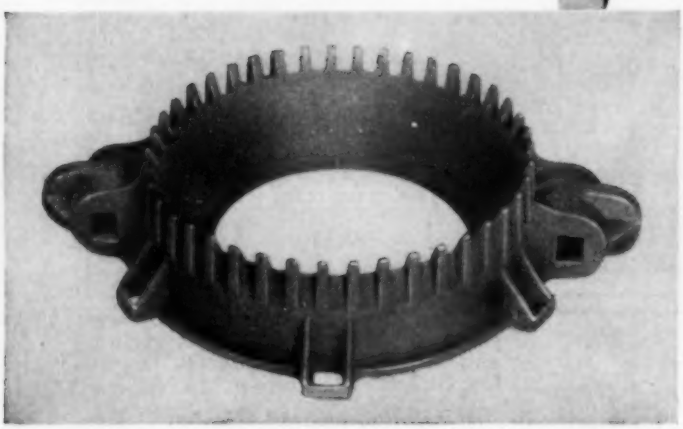
Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

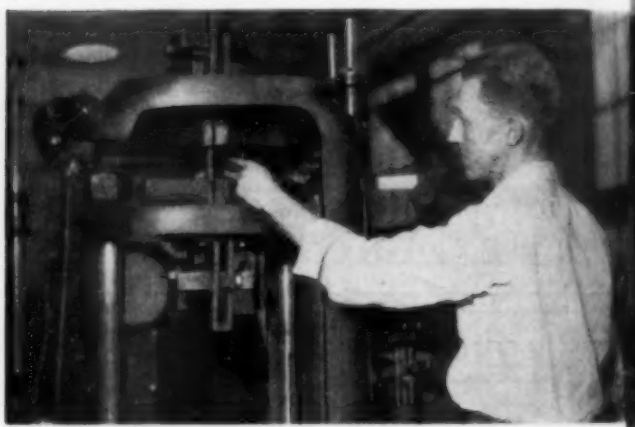
Use Handy Coupon on Page 768 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 768, 770, 772, 775, 778, 779, 782, 786, 788, 790, 792, 794, 798 and 806.

HOW TO ANNEAL MALLEABLE IRON QUICKLY, UNIFORMLY AND AT LOW COST

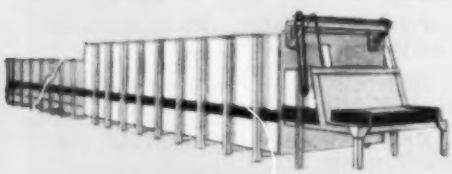
Uniformly annealed, malleable-iron castings of all types that easily meet highest-quality specifications —with the desired tensile strength, yield point, and elongation characteristics—can be obtained quickly, easily, and at unusually low cost by *short-cycle* annealing if your foundry is equipped with - - -



- - - the castings are clean and free of scale. Because of the tightness of the furnace, annealing is done with no objectionable decarburization. More important, every casting is completely and uniformly annealed, regardless of its relative position in the furnace. Standard test bars prove that - - -

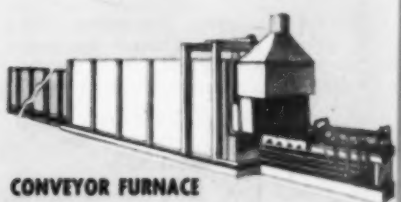


- - - high physical properties can be obtained consistently by annealing in G-E elevator furnaces. Rejects are few and far between. This is particularly important if your work must meet rigid specifications. Also, less supervision is required, and the time cycle is reduced. For example - - -

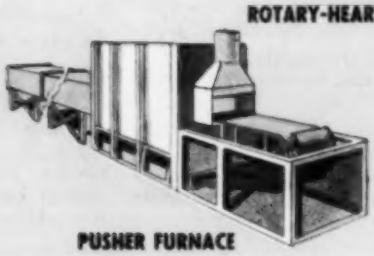


ROLLER-HEARTH FURNACE

ROTARY-HEARTH FURNACE



CONVEYOR FURNACE



PUSHER FURNACE

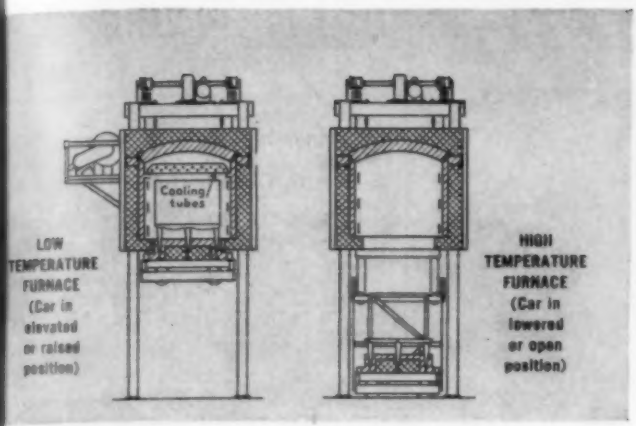
BOX FURNACE

PIT FURNACE

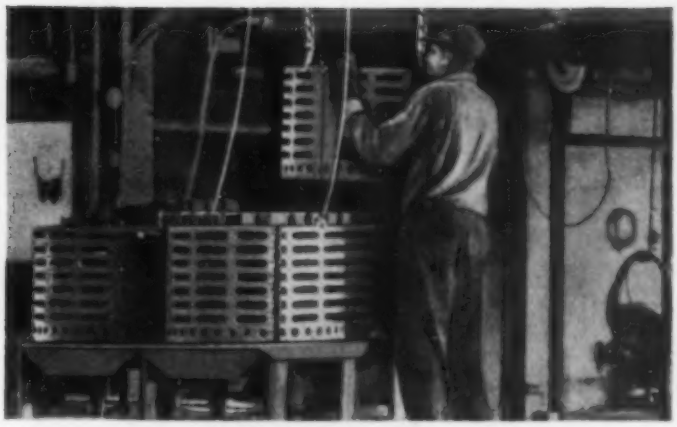
GE ELECTRIC FURNACES

FOR PRACTICALLY EVERY INDUSTRIAL NEED

BACKED BY A NATIONWIDE ENGINEERING SERVICE


Cooling tubes
LOW TEMPERATURE FURNACE (Car in elevated or raised position)
HIGH TEMPERATURE FURNACE (Car in lowered or open position)

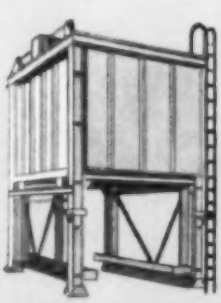
- - - two or more G-E electric elevator furnaces, one for the high-temperature, the other for the low-temperature cycle. Their uniform heat distribution insures uniform heating. Both are *gas-tight* and require no packing, closed containers, or separate source of atmosphere. Parts are simply loaded in - - -



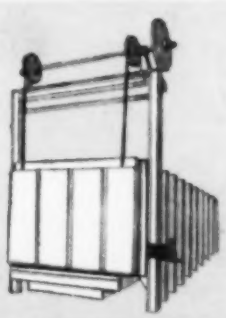
- - - light-weight, cast-alloy containers, or stacked directly on the furnace platform. Heat is not wasted on heavy containers. Therefore, both the heating and the cooling time are reduced, production is increased, costs are lower, and more uniform results are obtained. At the end of the cooling cycle - - -

- - - one typical malleable-iron foundry has reduced the total annealing time from 200 hours to 36 hours by changing from the use of "packed" furnaces to G-E elevator furnaces. In some cases, a continuous-type pusher or roller-hearth furnace may be advisable. For specific recommendations - - -

- - - get in touch with one of our many industrial-heating specialists, who are located in principal cities all over the country. These men have had many years of technical training and wide practical experience in all phases of industrial heating. Their detailed recommendations are quickly available. - - -



ELEVATOR FURNACE



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.....

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